Part 13
Strand 13
Pre-service science teacher education

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INTRODUCTION TO STRAND 13

PRE-SERVICE SCIENCE TEACHER EDUCATION

Pre-service science teacher education has been critiqued, studied and rethought since the creation of science teacher training programs, and despite the years of history and research in pre-service science teacher education, it still concerns our community. Pre-service teacher education is sometimes linked to students' outcomes and despite the changes in the science education teacher professional development, recent European reports point out that not only is the number of students choosing science declining, but the quality of science education in terms of relative attainment, is lower than expected in a number of countries.

The rise of inquiry-based science education in Europe led to a number of changes in the pre-service science teacher education, and innovations include developing pedagogies supporting scientific practices, skills and competences, and developing better understanding of the nature of science. However, questions such as what should the emphasis be on pre-service science teacher training, how can we improve the skills, scientific practices and competences of our pre-service science teachers, and what can we learn from other more successful systems still remain unanswered and are discussed amongst science educators.

The papers included in this volume illustrate the trends in pre-service science teacher education across the world currently, and provide examples of effective frameworks, teaching approaches and curricula that can support pre-service teachers in their teaching and learning efforts. We hope that this collective volume will become the basis of conversations discussing the changes and challenges in pre-service science teacher education across Europe and the world.

Maria Evagorou and Marisa Michelini

EMPIRICAL VALIDATION OF A COMPETENCY MODEL FOR SCIENCE TEACHING

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Abstract: In the field of teaching competency, research has focused so far on content knowledge (CK) and pedagogical knowledge (PK). In science and mathematics education research, pedagogical content knowledge (PCK) is traditionally closely related to CK. Our study bridges the whole range of teaching competencies and investigates the relationship between PK, PCK and CK. We report on a new competency model for science teaching that was validated by means of an open answer vignette test applied to N=344 teacher students. The model derives from multidimensional scaling and confirmatory factor analyses. We found evidence for transformative and integrative facets of teaching competencies in both the surface structure and the deep structure. In conclusion, PCK does not seem to be a construct of its own in science education. In the deep structure of teaching competencies, we found a facet that can be called *learner oriented professionalism in science* as the result of a transformation. In the surface structure of teaching competencies, the facet *specialized teaching methods* also results from a transformation. However, these two facets are not an amalgam of PK and PCK, but just intersections or accumulations of some aspects of PK and CK. Finally, implications for teacher training programs are discussed, e.g. the acquisition of curricular CK must be tightly coupled with some aspects of PCK in order to enable the teacher students to build a professional instructional repertoire.

Keywords: teaching competencies, competency model, pedagogical content knowledge, science education, vignette test

THE MODEL OF PROFESSIONAL COMPETENCIES

Pedagogical content knowledge (PCK) is considered the primary competence for science teaching. However, it remains unclear what PCK really comprises (Gess-Newsome, 1999; Gramzow, Riese & Reinhold, 2013): Is PCK a separate domain in addition to PK and CK (the so-called additive model), an intersection of PK and CK (the so-called integrative model) or can we consider PCK as an amalgam of PK and CK (the so-called transformative model)?

While in German-speaking countries pedagogical content knowledge is largely seen from the perspective of a formal education concept, the Anglo-Saxon tradition goes for a literacy concept (AAAS, 1993; Bybee, 2002; Klieme, 2003). Consequently, this leads to slightly different interpretations of professional teaching skills. German experts (e.g. Baumert & Kunter, 2006; Borowski, Neuhaus, Tepner, Wirth, Fischer, Leutner et al. 2010) postulate PK, PCK and CK in an additive approach, seen as three separate constructs. In contrast, in the integrative model PCK is not considered to be independent from the other teaching competencies, but to be fed from science knowledge and pedagogical skills (Magnusson, Krajcik & Borko, 1999; Park & Oliver, 2008). The professional teacher is therefore either a scientifically well-trained teacher or a pedagogically well-trained scientist. In the third approach, PCK is described as a domain of its own, significantly important for teachers' professional skills. CK and PK are considered to be transformed to PCK as a special amalgam of professionalism and pedagogy that leads to the professional self-image of the teacher (Shulman, 1987).

In order to determine which of the three above-mentioned interpretations is most closely consistent with empirical data, a theory-based competency model was developed. On the one hand, this competency model must contain all significant professional requirements a teacher has to meet in order to teach science, on the other hand, the model must allow a comparison of the three interpretations. We established our model by combining two widely-discussed competency models (Baumert & Kunter, 2006; Kunter & Trautwein, 2013). It consists of seven facets of teaching competencies: *general teaching methods, diagnosis of student perspectives, learning support, subject related teaching methods, diagnosis of preconceptions*, *cognitive activation* and *specialized content knowledge* (Fig. 2). By analyzing the data set of our vignette study (Brovelli, Bölsterli, Rehm & Wilhelm, 2014) empirical evidence for the structure of the competency model can be obtained (correlations of the seven facets of teaching competencies and their relation to Shulman's theory of knowledge), which implies the following questions to be answered:

- Can we confirm an additive, integrative or transformative model of professional competencies in science teaching?
- Which implications are to be considered for the curriculum of science teacher education?

METHODS

A test with eight text vignettes was developed. The test uses authentically complex teaching situations with an open answer format (Brovelli et al., 2014). It assesses three facets of pedagogical content knowledge (PCK) and compares them to three facets of pedagogical knowledge (PK) and one facet of content knowledge (CK). The instrument contains eight extended teaching situations in text format for biology, chemistry, physics and integrated science. The teaching contents are chosen for authenticity and for coverage of professional competencies that are generally agreed on to be necessary for successful science teaching in literature (Baumert, Kunter, Blum, Brunner, Voss, Jordan et al., 2010; Hattie, 2009; Riese & Reinhold, 2012).

The teacher students were asked to give a written feedback on the teaching situations. Using a coding manual, answers were rated by means of qualitative content analysis (Mayring, 2000) and a partial credit rating system (0/1/2) (Brovelli, Bölsterli, Rehm, & Wilhelm, 2013). In total, 344 university students from Germany (N = 194) and Switzerland (N = 150) participated in the study. Therefore, the sample consisted of 150 students from a teaching program based on a combined form of science teaching (integrating biology, chemistry and physics to one discipline) and of 194 students from a program teaching biology, chemistry or physics in separate disciplines. Participants were 17 to 46 years old (mean = 24.64, SD ± 4.02) and 67% were female.

In a first step, the competence areas CK, PCK and PK were explored. To this end, an exploratory factor analysis was conducted to select the items. Items with very low factor scores (< .30) were eliminated iteratively. In a second step, multidimensional scaling (MDS PROXSCAL) was performed in SPSS to look for coherent latent structures, that is, for an inductive model of teacher competencies (Fig. 1).

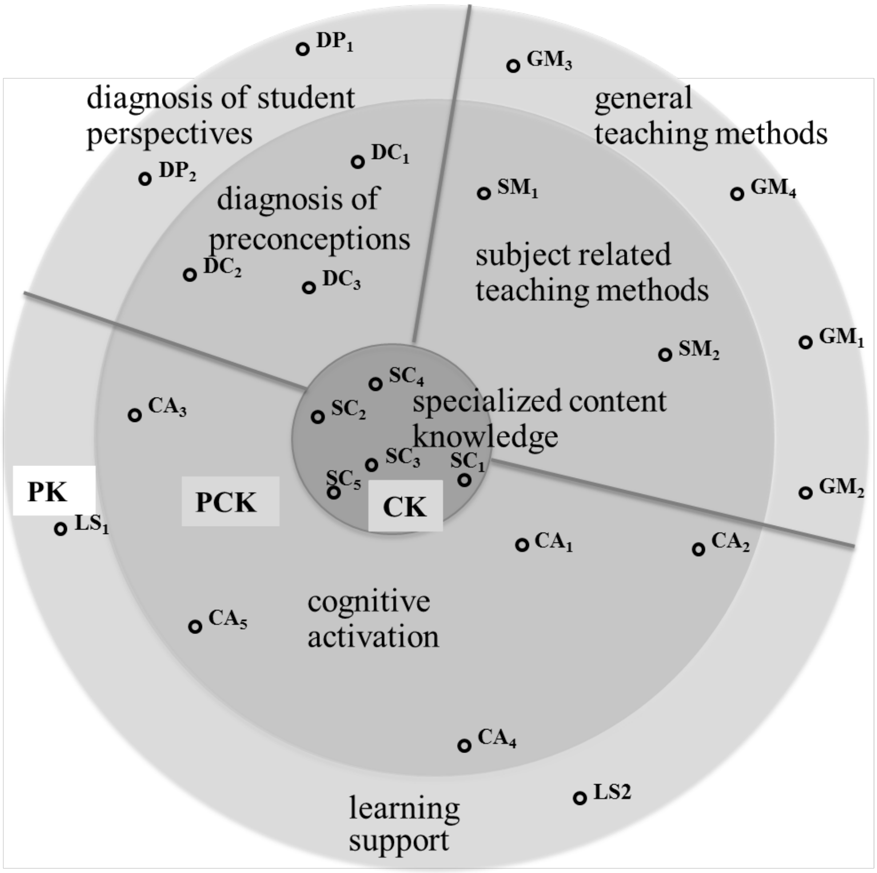

Figure 1: MDS structure (PROXSCAL, Roh-Stress = 0,119)

Subsequently, a confirmatory factor analysis (CFA) was performed in Amos to test the fit of the data to this inductive model and to calculate correlations between the seven facets of teaching competencies. Finally, we tested the fit of several models with confirmatory factor analysis and selected models with Chi-square tests to generate an education profile for teacher students.

RESULTS

The model fit of the initial CFA-solution with 23 items and seven facets of teaching competencies (*general teaching methods*, *diagnosis of student perspectives*, *learning support*, *subject related teaching methods*, *diagnosis of preconceptions*, *cognitive activation*, *specialized content knowledge*) was not very satisfactory (RMSEA=.042, CMIN/df=1.600, CFI 0.643). Moreover, several correlations between those facets scored higher than 0.70 (Fig. 2). Therefore, we decided to combine the constructs with the three highest correlations respectively: *general teaching methods* with *subject related teaching methods* (*r*=.74), d*iagnosis of student perspectives* with *learning support* (*r*=.84) and *diagnosis of preconceptions* with *cognitive activation* (*r*=.88). Again, a confirmatory factor analysis (CFA) was performed.

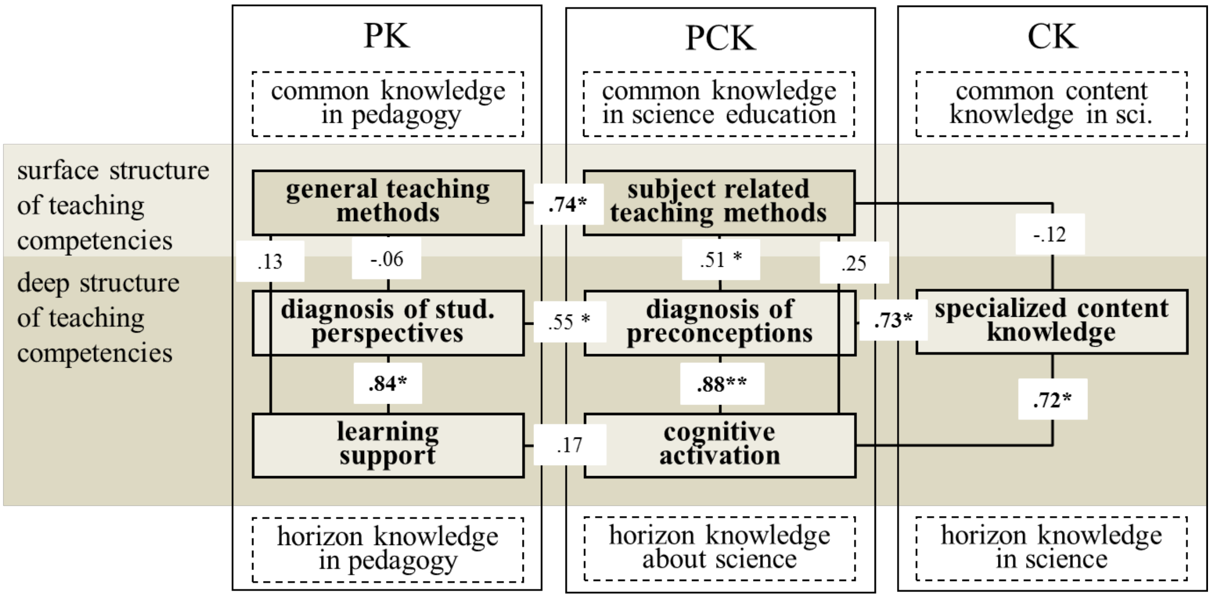

Figure 2: Model with seven facets of teaching competencies (23 Items, RMSEA=.042, CMIN/df=1.600, CFI 0.643)

The re-modelling led to a plausible reduced model with four facets, also from a theoretical viewpoint (Fig. 3). However, the model-fit was still weak (RMSEA=.041, CMIN/df=1.513, CFI=0.725). Correlations of the latent variables were highest between *specialized content knowledge* and the new dimension of *diagnosis of preconceptions and cognitive activation* (r=.77) and lowest between *specialized content knowledge* and *teaching methods* (r=.19).

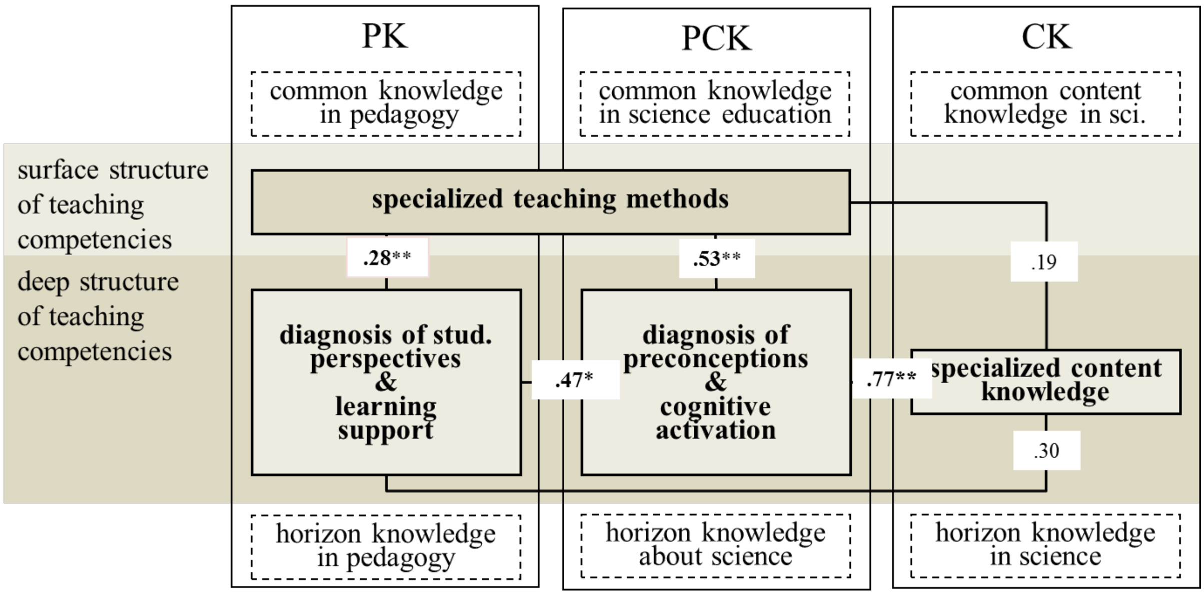

Figure 3: Model with four facets of teaching competencies (23 Items, RMSEA=.041, CMIN/df=1.513, CFI=0.725)

A further re-modelling led to a theoretically plausible reduced model with three facets (Fig. 4). A last confirmatory factor analysis (CFA) was performed and still the model fit is not perfect but acceptable (RMSEA=.041, CFI=0.876). A CFI between 0.8 and 0.9 is reasonable considering the mixed methods approach of this survey using text vignettes with authentically complex teaching situations in an open answer format.

This approach leads to a very high external validity but lower internal validity (Jeffries &

Maeder, 2011; Kersting, Givvin, Sotelo & Stigler, 2010; Voss, Kunter & Baumert, 2011). Considering the methodological approach, the model with the three facets *specialized teaching methods*, *adaptive learning support*, *learner-oriented professionalism in science* fits rather well. Correlations of the three latent variables are significant. This means that the three facets of teaching competencies build one construct while being three independent scales. The correlations between the surface structure for teaching competencies and the deep structure for teaching competencies are moderate: lowest *r*=.254 and highest *r*=.578. The correlation between the two facets within the deep structure is high (*r*=.737).

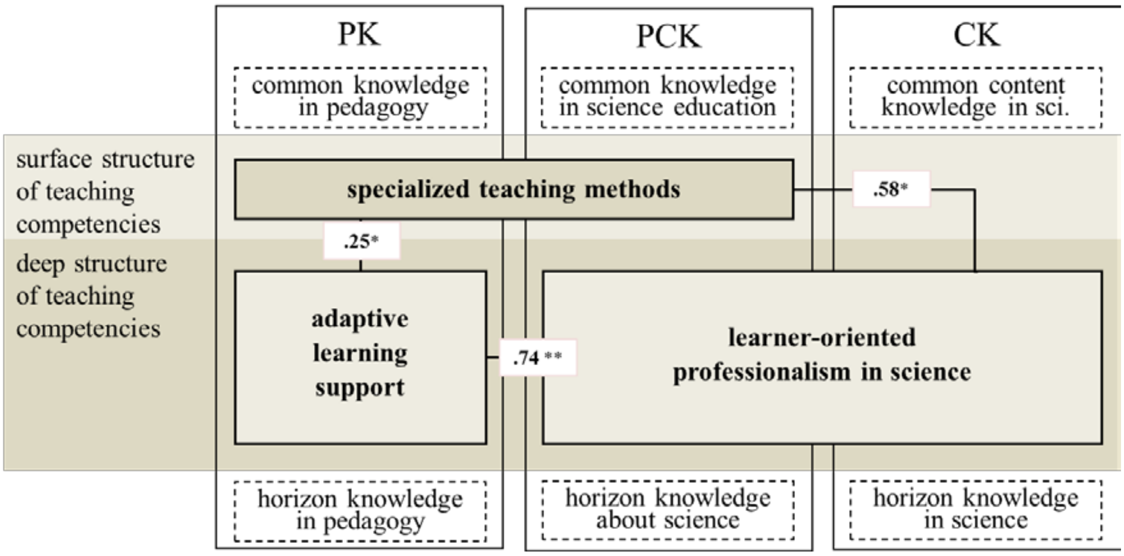

Figure 4: Model 3 with three facets of teaching competencies (15 Items, RMSEA=.041, CFI=0.876)

Results from the cross-sectional study strengthen the three factor model (Table 1). Predictors for *teaching competencies in specialized teaching methods* are mainly the teaching experience and being female. Whereas teaching experience mainly predict the facet of *learner oriented professionalism in science*. Gender plays a subordinate role. The only predictor for the facet of *adaptive learning support* is teaching experience.

Table 1: Teaching competencies and independent variables (gender, teaching experience, studying sciences), multivariate analysis of variance (MANOVA)

	Wilks' λ	Signi-ficance	Partial η^2	Teaching competencies	F	Signi-ficance	Partial η^2
				Learner-oriented professionalism in science (PCK-CK)	3.847	.051	.011
Sex (being female)	.964	**.006**	.036	Specialized teaching methods (PK-PCK)	11.686	**.001**	.033
				Adaptive learning support (PK)	4.496	**.035**	.013
				Learner-oriented professionalism in science (PCK-CK)	54.078	**<.001**	.020
Teaching experience	.862	**<.001**	.138	Specialized teaching methods (PK-PCK)	26.995	**<.001**	.020

				Adaptive learning support (PK)	40.095	**<.001**	.001
				Learner-oriented professionalism in science (PCK-CK)	.229	.633	.001
Number of semesters	.971	**.019**	.029	Specialized teaching methods (PK-PCK)	.063	.802	.020
				Adaptive learning support (PK)	1.522	.218	<.001

R^2=.183, learner-oriented professionalism in science (PCK-CK)
R^2=.185, specialized teaching methods (PK-PCK)
R^2=.200, adaptive learning support (PK)

DISCUSSION AND CONCLUSION

By using correlation values between the facets of teaching competencies as a criterion, we found evidence for some additive (r<.50), integrative (.50 <r<.75), and transformative (r> .75) models. In contrast to Shulman (1987), Gess-Newsome (1999) or Baumert and colleagues (2010), PCK for science education does not seem to be a construct of its own. In the deep structure of teaching competencies, we found a facet that can be called *learner oriented professionalism in science* as the result of a transformation. In the surface structure of teaching competencies, *specialized teaching methods* result from a transformation, too. However, these two facets are not an amalgam of PK and PCK, but just intersections or accumulations of some aspects of PK and CK. (Fig. 5). In conclusion, there seems to be gap between the deep structure of teaching competencies and the surface structure dividing PCK in two parts. Hence, PCK in science education seems to be a transformative-integrative construct, on the one hand strongly related to PK (*specialized teaching methods*) and on the other hand to CK (*learner oriented professionalism in science*).

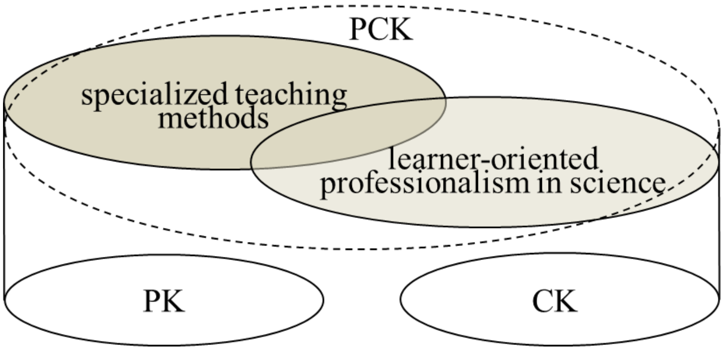

Figure 5: PCK as a transformative-integrative model with CK and PK as central auxiliary sciences

These results lead to some implications for teacher training programs. We need teacher training courses in learner oriented professionalism: Specialized content knowledge must be tightly coupled with the diagnosis of preconceptions and cognitive activation within the PCK construct. Moreover, we need teacher training courses in specialized teaching methods: They should address specific teaching cases with both an educational and a subject-oriented focus. CK and PK can be regarded as the two vital auxiliary disciplines for learning the two facets of PCK.

Finally, we have to reflect on some limitations of our survey: With a sample of 344 teacher students from only two countries, this study merely allows us to show some trends. In addition, by only rating written feedbacks on teaching situations we did not take into account e.g. the ability to carry out experiments and use models or other special expertise and skills. Nevertheless, the empirically validated competency model for science teaching represents a first contribution to further discussions.

REFERENCES

American Association for the Advancement of Science (AAAS) (1993). *Benchmarks for Science Literacy.* Washington, DC: AAAS.

Baumert, J., & Kunter, M. (2006). Stichwort: Professionelle Kompetenz von Lehrkräften. *Zeitschrift für Erziehungswissenschaft, 9*(4), 469–520.

Baumert, J., Kunter, M., Blum, W., Brunner, M., Voss, T., Jordan, A., Klusmann, U., Krauss, S., Neubrand, M. & Tsai, Y.-M. (2010). Teachers' mathematical knowledge, cognitive activation in the classroom, and student progress. *American Educational Research Journal, 47,* 133–180.

Borowski, A., Neuhaus, B. J., Tepner, O., Wirth, J., Fischer, H. E., Leutner, D., et al. (2010). Professionswissen von Lehrkräften in den Naturwissenschaften (ProwiN): Kurzdarstellung des BMBF-Projekts. *Zeitschrift für Didaktik der Naturwissenschaften, 16*, 341–349.

Brovelli, D., Bölsterli, K., Rehm, M. & Wilhelm, M. (2013). Erfassen professioneller Kompetenzen für den naturwissenschaftlichen Unterricht – ein Vignettentest mit authentisch komplexen Unterrichtssituationen und offenem Antwortformat. *Unterrichtswissenschaft, 41*, 306–329.

Brovelli, D., Bölsterli, K., Rehm, M. & Wilhelm, M. (2014). Using Vignette Testing to Measure Student Science Teachers' Professional Competencies. *American Journal of Educational Research, 2*(7), 555-558.

Bybee, R. (Ed.) (2002). *Learning science and the science of learning.* Arlington, VA: NSTA Press.

Gess-Newsome, J. (1999). Secondary teachers' knowledge and beliefs about subject matter and their impact on instruction. In J. Gess-Newsome & N. Lederman (Eds.), *PCK and science education* (pp. 51–94). Dordrecht: Kluwer.

Gramzow, Y., Riese Josef, & Reinhold Peter (2013). Modellierung fachdidaktischen Wissens angehender Physiklehrkräfte. *Zeitschrift für Didaktik der Naturwissenschaften, 19,* 7–30.

Jeffries C. & Maeder D. (2011). Comparing vignette instruction and assessment tasks to classroom observations and reflections. *The Teacher Educator, 46*, 161–175.

Hattie, J. (2009). Visible learning: A synthesis of over 800 meta-analyses relating to achievement. London: Routledge.

Kersting, N., Givvin, K., Sotelo, F. & Stigler, J. (2010). Teachers' Analyses of Classroom Video Predict Student Learning of mathematics: Further Explorations of a Novel Measure of Teacher Knowledge. *Journal of Teacher Education, 61,* 172–181.

Klieme, E. (Hrsg.) (2003). *Bildungsreform. Bd. 1: Zur Entwicklung nationaler Bildungsstandards. Eine Expertise*. Bonn: BMBF.

Kunter, M., & Trautwein, U. (2013). *Psychologie des Unterrichts.* Paderborn: Schöningh.

Magnusson, S., Krajcik, J., & Borko, H. (1999). Nature, sources, and development of pedagogical content knowledge for science teaching. In J. Gess-Newsome & N. Lederman (Eds.), *Examining pedagogical content knowledge: the construct and its* *implications for science education* (pp. 95–132). Dordrecht: Kluwer.

Mayring, P. (2000). Qualitative content analysis. Forum: Qualitative Social Research, 1(2).

Oser, F., & Baeriswyl, F. (2001). Choreographies of teaching: Bridging instruction to learning. In V. Richardson (Ed.), *Handbook of Research on Teaching* (pp. 1031-1065). Washington: American Educational Research Association.

Park, S., & Oliver, J. S. (2008). Revisiting the conceptualisation of pedagogical content knowledge (PCK): PCK as a conceptual tool to understand teachers as professionals. *Research in Science Education, 38*(3), 261-284.

Riese, J. & Reinhold, P. (2012). Die professionelle Kompetenz angehender Physiklehrkräfte in verschiedenen Ausbildungsformen. *Zeitschrift für Erziehungswissenschaft, 15,* 111–143

Shulman, L. S. (1987). Knowledge and teaching: Foundations of the new reform. *Harvard Educational Review, 87*, 1–21.

Voss, T., Kunter, M. & Baumert, J. (2011). Assessing teacher candidates' general pedagogical/psychological knowledge: Test construction and validation. *Journal of Educational Psychology, 103,* 952–969.

CONVENTIONAL AND DIGITAL MICROSCOPY – DEVELOPING CELL CONCEPTUAL COMPETENCES USING THE EXAMPLE OF HUMAN BIOLOGY

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Abstract:

This study was done with the goal to promote the development of microscopy competences at school. Students in elementary biology classes are fascinated by microscopy. In higher classes, however, microscopy is hardly done. Students of upper levels feel challenged by the complexity of concrete configurations and have little practice working with these.

Is it possible to support and complement the understanding of cell concepts and the skills necessary to interpret histological structures through digital microscopy and use of the interactive whiteboard (IWB)? Is it possible to measure microscopy skills and the effects of interventions?

The current study investigated this problem in two ways.

First, pre-service teachers compared learning effects of self-developed modules with interactive whiteboards (IWB) with original microscopy (2012 n=70; 2013 25+14; 2013/14 n=21+27; 2014 n=40) using the example of human biology. Most biology teacher trainees perceive themselves as having average microscopy skills. This study examines the development of these students' skills. Questionnaires (short scale of intrinsic motivation, flow, and interpretation of microscopic images) and interviews were used to collect data. The results show that the use of the whiteboard is valued because of the possibility to make visible connections and put these into a context. The use of the whiteboard does not, however, surpass the motivation and flow of real microscopy in problem-oriented learning processes. The IWB is a good supplement but is not a substitute for the microscope. When initial technical problems have been overcome, digital images can achieve similar effects to conventional images, in a collaborative approach.

Second, eye movements (eye tracking) of 12th grade students were measured during histological image processing of retina and nervous tissues (2013 n=11+26). We measured that the fixation in the area of interest (AoI) corresponded with the level of prior knowledge. The qualitative analysis of the scan path of histological images of sensory and nervous cells, however, allows conclusions about concrete cognitive aspects of attentive image comprehension.

Keywords: eye tracking, microscopy, interactive whiteboard, retina, NOS

INTRODUCTION

Developing competences through digital and conventional microscopy

„Omnis cellula e cellula" (Virchow). Cells are the basic structure of all living things.
It is essential to grasp the concept of cells to comprehend the relationships between structures and functions of living things. Thus, microscopy is an important skill with which to acquire knowledge for a basic understanding of biology.
We would like to better understand why more both mature students and pre-service teachers have difficulties working with the microscope and which observation patterns they show. This seems necessary to develop meaningful didactic measures to improve microscopy at school. Among other things, we would like to examine in how far we can adapt digital histological images for school purposes.

In life sciences and medicine, microscopy is making huge developments and is indispensable. Learning how to meaningfully use the microscope is an essential school requirement connected with grasping the "Nature of Science" (NOS). Working with the microscope must not only be seen as a technical part of lab work but also as a skill with which to gain knowledge of biology. The following steps belong to our model of microscopy skill development (Jäkel, 2012):
level 1- basic practical knowledge of the use of the microscope;
level 2 - conviction of the usefulness of using the microscope in different situations;
level 3 - use of the microscope specifically to clarify scientific phenomena (scientific reasoning);
level 4 - appropriate use of the microscope in biology is associated with a clear understanding of the cell concept of living beings (epistemological views).
One of the reasons for the scarcity of microscopy in connection with demanding contents at school may be inadequate technical equipment. We believe, however, that the competence of future teachers is the essential prerequisite for active instructional implementation. We were able to reveal how interest of pre-service teachers (Jäkel, 2012) in microscopy increased through problem-based learning (see Crawford, 2014).

School projects connected to microscopy (e.g. Amano, Yamanaka, & Kawakami, 2014) in which physicians and cell biologists were to some extent involved (e.g. Korres et al., 2014) were not ultimately orientated toward technical skills but rather toward grasping the NOS.

In Japan, a "microscopy-license" with 9 workshops was developed and trialed on two groups of students (Amano, Yamanaka, & Kawakami, 2014). „As a whole, although the participants found the program difficult, they were satisfied because they were able to learn a variety of things and their interest in science was heightened."

Experiencing flow is of particular concern because microscopy, as a process of recognition, is a sophisticated activity (compare with Amano, Yamanaka, & Kawakami, 2014). Rheinberg et al. (2003) distinguished between demand and challenge of the activity. When working with histological images, the initially unaccustomed but required operation of the interactive whiteboard (IWB) is added to the complexity of the cellular configurations. Using a whiteboard, the images can be manipulated, linked, or labeled using a pen or by hand (figure 1). Flow means "being completely wrapped up in a task that is running smoothly and that, despite strain, one still has under control. This state is generally perceived as being pleasant" (Rheinberg et al., 2003).

Image processing

Studies show contradictory findings on the use of images. Schematic images may cognitively be more effective than real images because they don't distract the observer through details. Microscopic images, however, are highly complex and can overwhelm inexperienced observers. The Cognitive Load Theory (Sweller, Van Merrienboer, & Paas, 1998) offers explanations to what extent the spatial proximity of multiple sources of information influences the cognitive burden of learners. The cognitive theory of multi-media study (Mayer, 2005) deals with the integrative processing of text and image. Thus, the principle of contiguity is valid. It is believed that motivational factors and learning strategies influence learning by raising or lowering cognitive involvement.

Both conscious and subconscious decisions play roles in attentiveness and fixation when regarding images. Saccades occur between the fixations. Attentive processing is the conscious and targeted processing of images in accordance with certain criteria. In pre-attentive processing, an image is intuitively processed as a whole.

Figure 1. Using the IWB, the histological images can be manipulated, using a pen or by hand.

Eye Tracking

Yarbus (1967) conducted fundamental research on eye movements. Nowadays, eye movements can be accurately recorded using a computer (e.g. Mack, & Ilg, 2014). A scan path is documented. High quality eye movement studies are time-consuming because of the required exact calibration, while the sample sizes remain small. The results of accurate scan paths are, however, a resource for understanding image processing and histology comprehension.

Eye movement studies in media studies or fine arts offer (e.g. Quiroga, & Pedreira, 2011) clues about interaction among the text and the image, the user interface, and the role of prior knowledge. According to this, visual-spatial content, for example, is learned better close to the hands, and semantic content is learned better farther away from the hands (Brucker et al., 2014). This might be important when designing learning modules for interactive whiteboards.

Visual expertise is of crucial importance for clinical pathologists. Banzhaf et al. found differences between novices and those experienced in dermoscopy recognizing Melanoma in histological images (n=25). „Novices had a longer and more complex gaze track pattern“(Banzhaf, Lund, Zarchi, Lorentzen, Argenziano, & Jemec, 2013).

The studies of eye movement showed, however, that histologists exhibit a more target oriented scan path than novices (Jaarsma et al., 2013). Jaarsma et al. (2013) compared pathologists (n=13), residents (12), and medical students (13). They diagnosed 10 static, colored microscopic images within 2 seconds of viewing time per image. Intermediates seemed to check; experts explored. Results show that novices fixate less in Areas of Interest (AOI), often diagnose incorrectly, and are vague and incorrect in their explanations.

The establishment of digitally supported microscopy began in medical studies (e.g. Romer, Suster, 2003, Scoville, & Buskirk, 2007). No significant difference in diagnostic accuracy was detected between the diagnoses proffered on the basis of virtual slides and conventional slides; using virtual slides, though, took pathologists considerably longer (Furness, 2007). Precise feedback is necessary for the identification of relevant configurations (Merk, Knuechel, & Perez-Bouza, 2010).

QUESTIONS

What do experts and novices gaze at when using a microscope or when processing a histological image?

Is it possible to verify the stimulating effect of problem-centered work in eye movement recordings using histological images? Does the number of saccades or fixations, respectively, correspond with the expert status of students?

Does the IWB support necessary microscopy competences, such as the ability and willingness to specifically align histological images while acquiring insight and solving problems?

METHODS

The study investigates histological image processing in two methodological ways:
first, comparison IWB/ conventional microscopy,
second, eye tracking.

Comparison IWB and conventional microscopy

The use of digital histological images was compared with the conventional use of the microscope by examining human biological learning processes. Specific microscopic images (lungs, kidney, skeleton, muscle, blood, heart, gonads, and nervous system) were integrated into learning modules for the IWB. They focused on problem-based tasks that were discussed in small groups and accompanied by a tutor.

All students of one semester, studying to become teachers of biology, were test persons in both procedures (figure 2). The short questionnaire about intrinsic motivation (Ryan and Deci's intrinsic motivation inventory IMI) was employed every session. The Flow short questionnaire (Rheinberg et al., 2003) was employed several times. Additionally, tests were done to assess interest in biology (pretest/posttest). Special knowledge tests connected with the concept of cells were conducted three times throughout the semester.

Procedure of the main study (IWB/ microscopy):

Total group of students: Pretest about interest in biology

Pretest about interpretation of microscopic images

5 seminars on human biological topics, each with intrinsic motivation inventory (IMI)
and optionally

individual use of conventional specimen and microscopes

use of the IWB with the support of a tutor in small groups

Interim test on cellular interpretation of microscopic images

6 seminars on further human biological topics, each with IMI, in part with FLOW-questionnaires
and optionally

individual use of conventional specimen and microscopes

use of the IWB with the support of a tutor in small groups

Posttest on interests in biological domains

Posttest on interpretation of microscopic images

Figure 2. Procedure of the main study (IWB/ microscopy) The studies continued through multiple semesters from 2012 to 2015.

Eye tracking methodology

Tracking eye movement patterns requires special apparatus (Arrington Research USB220, frequency 220 Hz, the spatial resolution is 0.01°). Students of higher secondary school were observed while examining histological images at a student laboratory of neuro science in Tuebingen. Tower-mounted high quality eye-tracking recordings (noninvasive infrared oculography) were done in August 2013 on 11 subjects (six males, five females) and in October 2013 on 26 subjects (twelve males, seventeen females, aged 17-19) sitting comfortably in front of a computer screen on which each image was shown for 6 or 12 sec. The six stimuli during the first measurement series were spinal cord, motor neurons, cerebellum, purkinje cells, retina, and optic nerve; the two stimuli during the second measurement series were retina (400 x optically magnified) and optic nerve (100 x optically magnified). We measured intensity and duration of fixation of each student during the 6 or 12 seconds of presentation of each stimulus (optic nerve, retina …). The eye movements were documented for six seconds in the first series of measurements and for twelve seconds in the second series. Microscopic images of the retina (figure 3) and the blind spot with the optic nerve (figure 4) were used as stimuli. The total number of saccades and fixations were documented (software MathWorks, Inc., Natick, Massachusetts, U.S.). The test subjects were each given the task to identify certain cell structures.
The procedures of the main study with high speed, tower-mounted eye tracking included a pretest on interest in biology and a short interview following the scan path measurement.

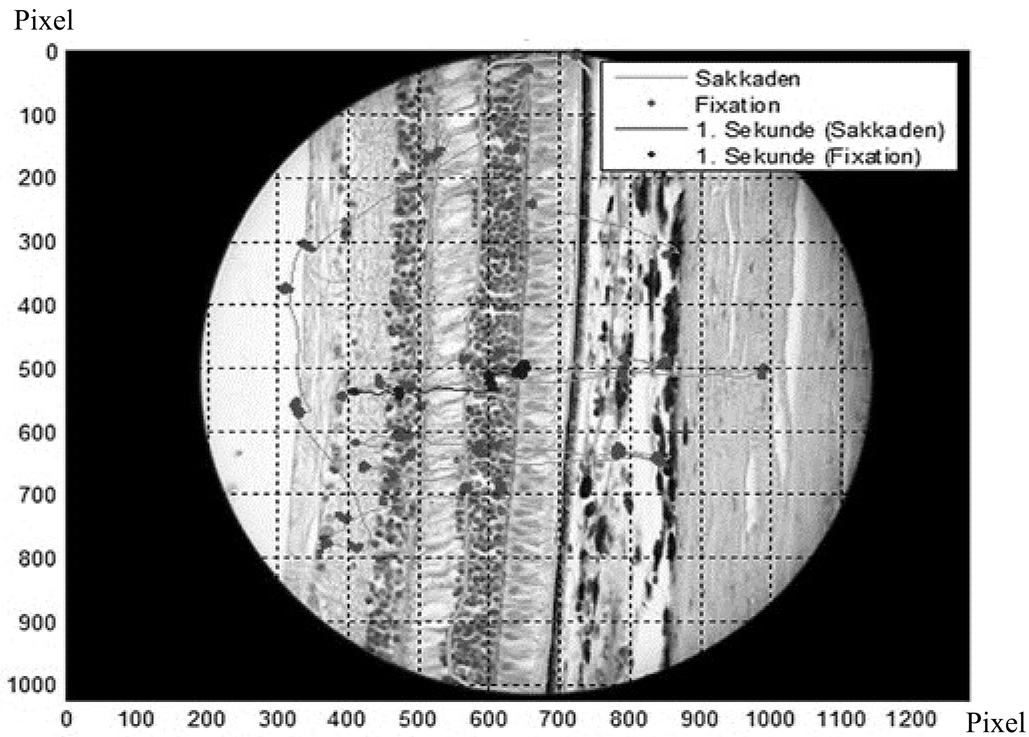


Figure 3. Example of a scan path of eye movements when gazing at the histological image of the retina: In this measurement series 1, six stimuli (spinal cord, motor neurons, cerebellum, purkinje cells, retina, and optic nerve) are documented, each six minutes long.

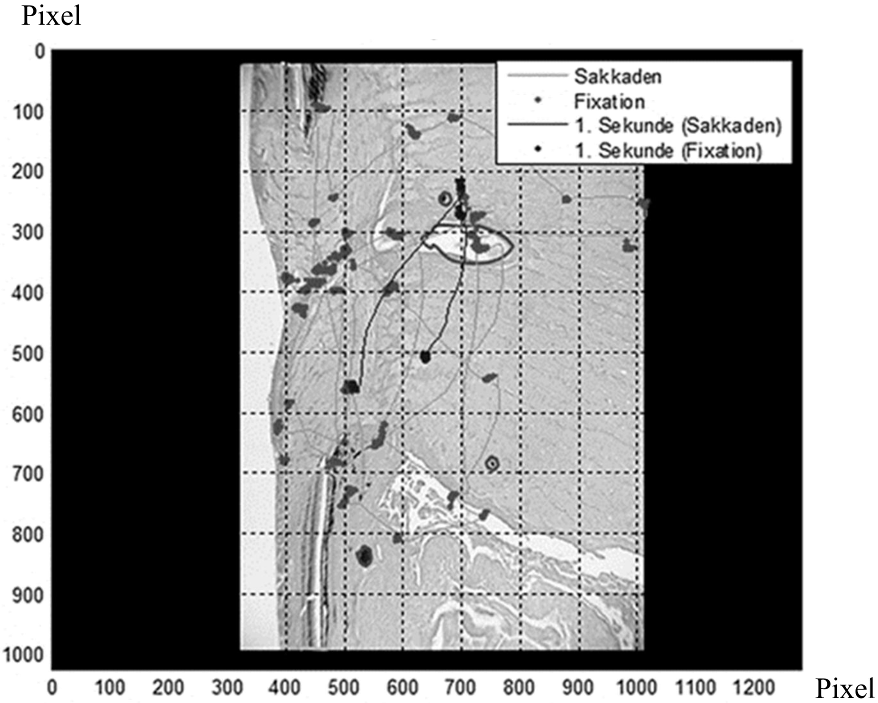


Figure 4. Example of a scan path of eye movements when gazing at the histological image of the optic nerve: The stimulus was presented 12 seconds long (measurement series 2). Neither the retina nor the optic nerve were recognized by the test subject despite good knowledge of anatomy and despite the fact that the blind spot is part of the curriculum.

	Pretest M (SD)	Posttest M (SD)
Botany	3.19 (1.41)	3.17 (1.78)
Zoology	2.5 (1.66)	2.63 (1.42)
Human Biology	2.15 (1.66)	2.09 (1.42)
Molecular Biology	3.53 (1.61)	3.28 (1.38)
Ecology & Environment	2.79 (1.61)	2.67 (1.45)
Outdoor Biology	2.93 (1.62)	2.73 (1.22)
Interest in microscopy with drawing	5.1 (1.87)	4.63 (2.18)
Interest in microscopy without drawing	2.88 (1.73)	2.43 (1.5)
Microscopy competences	3.55 (1.73)	2.7 (1.07)

Table 1. Interest in fields of biology and microscopy competence n=40 summer semester 2014

RESULTS

Comparison IWB/ microscopy

The instruments were questionnaires (short scale of intrinsic motivation, flow, and interpretation of microscopic images) and interviews.

Pretests and posttests were used to assess interest in the field of biology. Table 1 shows interest in various domains of biology and self-perception of microscopy competence in 2014 as an example. These results are reproducible, recurring annually. The variable ‘interest in human biology’ correlates with the variable ‘self-perception of competence in microscopy’. Interest in human biology is highly resistant. Interest in microscopic drawing is low.

The second instrument was a short questionnaire about intrinsic motivation (Ryan and Deci’s intrinsic motivation inventory IMI) and was employed every session. The situational interest in the IWB or microscopy does not depend on the time invested (see figure 5).

The third instrument was a special knowledge test. Competences in cellular interpretation of microscopic images (e.g. blood and retina) of both treatments increased significantly from the beginning to the middle and again to the end of the seminar.

Additionally, the Flow short questionnaire (Rheinberg et al., 2003) was employed several times. The flow experience overall reached approximately the height of graffiti or computer games (Rheinberg et al., 2003) (table 2). The IWB even provides students in a small group with a free choice of approach, which can lead to somewhat more flow than the use of conventional microscopes (table 2).

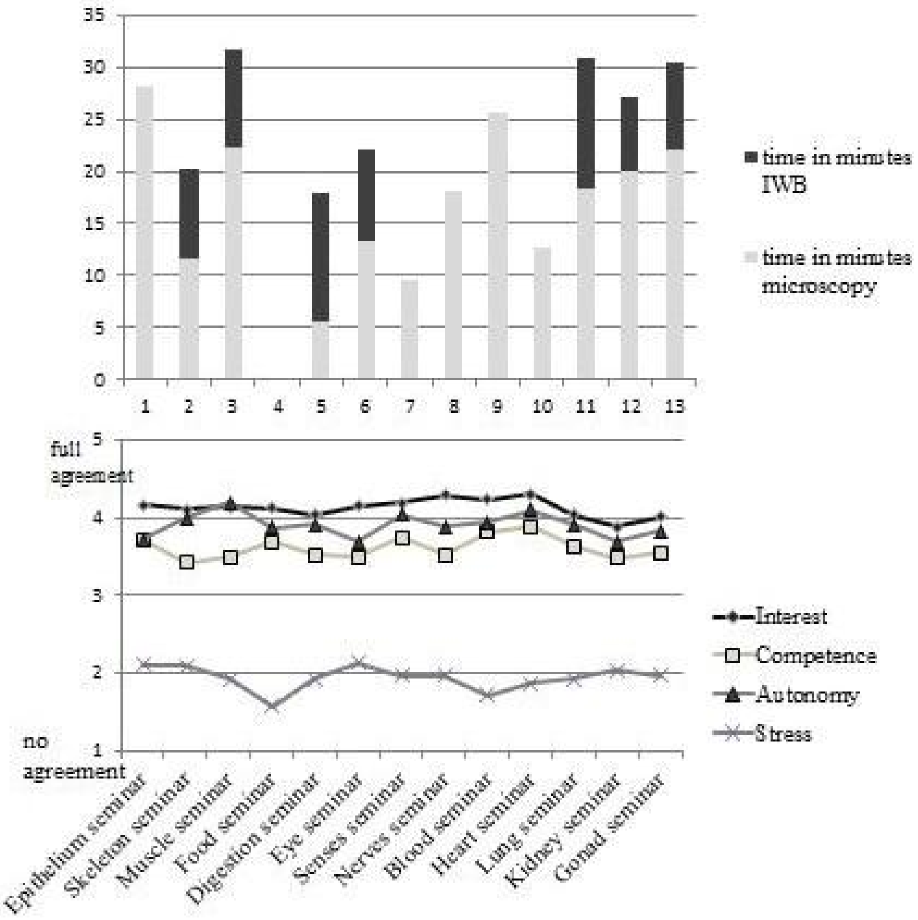
The positive values of interest and ratio of matching requirement of conventional microscopy using problem-based learning are not surpassed, however, by learning with digital images (figure 5).

learning activity	semester	matching with demands 9-stepscale Mean (SD)	total flow 7-stepscale Mean (SD)	absorption 7-stepscale α=0.732 4 items Mean (SD)	smooth process 7-stepscale α=0.852 6 items Mean (SD)	anxiety 7-stepscale α=0.835 3 items Mean (SD)
microscope blood n=23 course1	2013/14	4.74 (1.096)	4.8 (1.52)	5.1 (1.5)	5.0 (1.3)	3.2 (1.9)
microscope blood n=27 course 2		5.50 (1.105)	5.0 (1.4)	5.0 (1.53)	4.67 (1.53)	3.09 (1.49)
microscope kidney course n=17		5.50 (0.437)	4.81 (1.39)	4.92 (1.51)*	4.73 (1.3)	4.4 (1.85)
IWB kidney n=6		5.24 (0.753)	5.4 (1.32)	5.49 (1.44)*	5.33 (1.24)	5.05 (2.2)
IWB lung n=14	2014	5.64 (1.15)	4.72 (1.21)	4.95 (1.28)	4.65 (1.22)	4.88 (1.75)

IWB eye course 1 n=19	2014/15	4.84 (1.07)	4.71 (1.4)	4.66 (1.44)	4.75 (1.37)	3.09 (1.67)
microscope eye course1 n=12		5.25 (0.96)	4.77 (1.54)	4.88 (1.51)	4.54 (1.53)	3.3 (1.91)

Table 2. Measurement using the flow short scale (Rheinberg et al., 2003) (13 Items, 7-step-scales) and the additional item: „The current demands are ….too low ….exactly right …too high for me (9-step scale)." *sign. difference: IWB/ microscopy

Figure 5. Example of the analysis of the IMI questionnaires for seminars 1- 13 in 2014: Legend: the bar chart specifically refers to the use of the interactive whiteboard and microscopes in minutes, the graph corresponds with the bar chart and shows the categories of situational interest, perceived competence, perceived autonomy of the learning process, and stress perception; the vertical scale of the graph shows mean response (n = 56) on a 5-point Likert Scale: 1 (no agreement) to 5 (full agreement). Additional measurements of other courses are available.



In the guidelines-based interviews, the participants were asked to distinguish between pros and cons of the IWB and original microscopy. They reflected on their own experiences with the tools and instructional guidance.

Advantages of real microscopy were seen in the individual sense of achievement by immediate preparation of specimens, e.g. oral mucosa, blood smears, and brain specimens. It was mentioned as being an additional motivational factor that does not exist with respect to the IWB.

The problem-solving oriented learning process of the IWB was considered to be one of its advantages; answering a specific question helped to understand the images. The IWB also offers a more compact overview on the overall context, and direct feedback supports comprehension of connections and functions of small tissues like marrow or cortex.

Negative aspects of the IWB are the immense amount of work as well as the technical difficulties.

Examination of eye movements

Within twelve seconds of observing the microscopic image (second measurement series), around 32 fixations occurred among the 26 test subjects, regardless whether these had expert or novice status. The arithmetic average of fixations for stimulus 1 (retina) is 32.8 (SD 3.74). The arithmetic average of fixations for stimulus 2 (blind spot) is at 34.03 (SD 3.67).

The total number of fixations and the expert status (three categories, determined in the interview and self-assessment) does not correlate. However, a larger proportion of fixations on the target cells occurred in test subjects with more knowledge. According to the model calculation (Mplus), there is a significant connection between expert status and the counted hits in the „Area of Interest" of stimulus 2 (ocular fundus with optic nerve). The number of hits in stimulus 1 and 2 are significantly different, not, however, the measured total number of saccades (t-Test) in stimulus 1 and stimulus 2.

The qualitative analyses show that only few subjects recognized the optic nerve and the retina segments in the image (stimulus 2 blind spot, see figure 4).

It is possible to distinguish between five strategies for searching for relevant structures in histological images of eyes and retina; some strategies led to the correct identification of light sensory cells.

- Focusing on contrasts and dark areas (choroid, pigment epithelium)
- Orientation on the side that is facing the light source (unsuccessful)
- Repeated comparison of closely related structures (bipolar cells, light sensory cells)
- Random search without concept (unsuccessful)
- Scanning the whole image and rapid fixation of the target cell (most successful)

DISCUSSION AND CONCLUSION

Digital histological images were used for the eye-tracking study, despite the technical possibilities. The results should be comparable to conventional microscopy according to studies of Furness (2007) see above.

The qualitative examination of the eye movements gives evidence to the advantages of problem-oriented observation of images by high school students. The eye movement analysis reveals obstacles in the comprehension of cellular configurations, for example, disorientation between bipolar cells and light sensory cells or between muscles and optic nerves of the eye. Images with higher magnification were less challenging than images with lower magnification. One reason could be that the relevant section had already been chosen by the investigators. If microscopic slides of histological images are colored differently from previously viewed images, students become confused.

Students overestimated the size of neurons and sensory cells and underestimated their number. Consequently, they had difficulties detecting them in histological images or were not able to at all because they had not have enough practice doing this. Practice seems to be indispensable for "learning to see" (see Kastenhofer 2004). To grasp the "Nature of Science," it seems important that the students understand the process of creating a schema by abstracting and reconstructing, beginning with the histological image. Textbook-schemata often show only individual cells. Through microscopy, students are supposed to more easily understand the connections between structure and function than through abstract representation only.

Pre-service student teachers reflected on advantages and disadvantages of the IWB in a differentiated manner. It is an immense amount of work to design interactive material. At the same time, learning material can be used often when different levels of learners are considered. Instructional designers, however, should consider the learners' level of expertise and their cognitive load when applying design principles (Rey, & Buchwald, 2011). When initial technical problems have been overcome, digital images can achieve similar effects to conventional images, in a collaborative approach. In our opinion, the importance of conventional microscopy is based on the opportunity to experiment individually.

Qualified feedback and clear research questions concerning conventional and digital microscopy appear to be conducive to learning. Combination of text and histological image is useful. Schemata alone are not sufficient to recognize cells and histological structures. Didactic preparation and consideration of prior knowledge are essential to reduce students' widespread reluctance concerning microscopy.

We do not expect all students to become histologists, so why should working with the microscope be so important at school? Hands-on microscopy must be seen as a plea for the transience of textbook-schemata. Using the microscope, students are supposed to understand the process of developing a scheme and have respect for the scientific work invested to create such a scheme. It should also promote curiosity. All in all, working with the microscope is supposed to promote grasping the "Nature of Science."

We thank Uwe Ilg and David J. Mack for the opportunity to use the Eye Tracking system in Tuebingen and, most of all, for their wonderful cooperation.

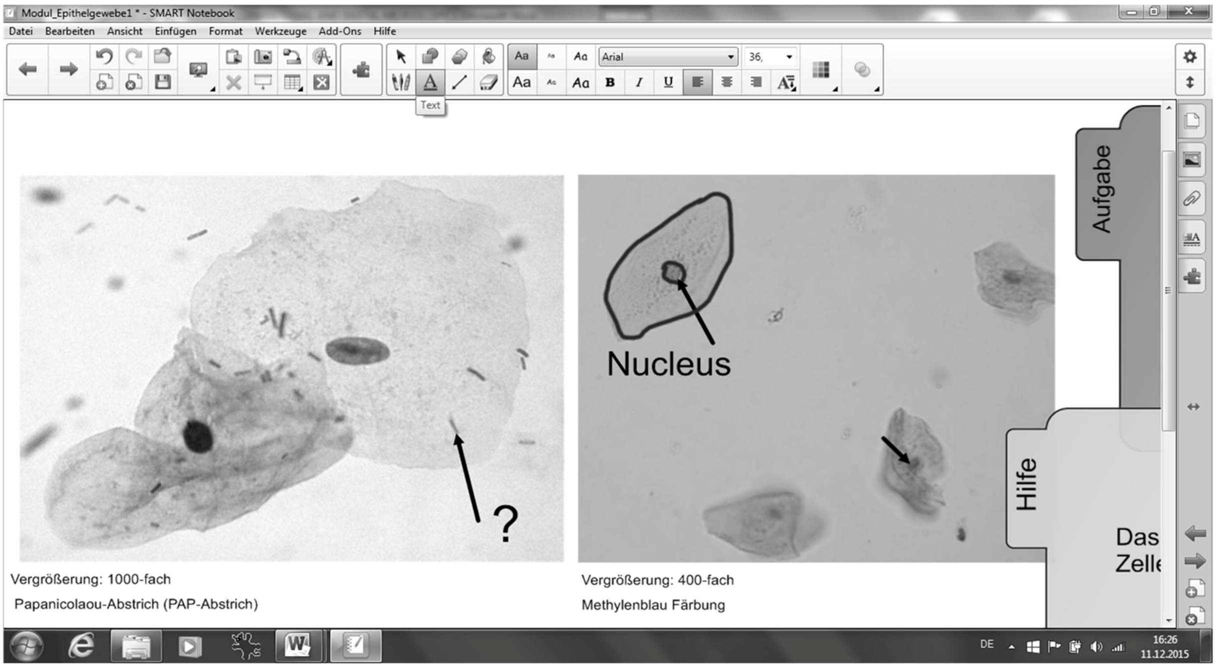


Figure 6. Example of a learning module for the IWB about epithelium

REFERENCES

Amano, J.; Yamanaka, A., & Kawakami, S. (2013). Advanced activities using microscopes at a science museum to strongly promote children´s interest in science. Nikosia: ESERA conference, September 2013, Cyprus.

Araújo-Jorge, T. C., Cardona, T.S., Mendes, C. L. S., Henriques-Pons, A., Meirelles, R.,

Coutinho, C., Aguiar, L. E. V., de Nazareth, M., Meirelles, L., de Castro, S., Barbosa, H.S., & Luz, M. (2004). Microscopy images as interactive tools in cell modeling and cell biology education. Cell Biol Educ. 3 (2), 99–110.

Banzhaf, C.A., Lund, H., Zarchi, K., Lorentzen, H. F., Argenziano, G., & Jemec, G. B. E. (2013). Recognizing Melanoma – Eye Movement Patterns in Dermoscopy – Differences between novices and those experienced in dermoscopy. 17. European Conference on Eye Movements, 11-16 August 2013, Lund, Sweden.

Brucker, B., Edelmann, J., Brömme, R., & Gerjets, P. (2014). The proximity of the hands to the objects influences learning on multi-touch devices. Proceedings of EARLI Special Interest Groups Instructional Design & Learning and Instruction. Rotterdam, Netherlands.

Crawford, B. A. (2014). From Inquiry to Scientific Practices in the Science Classroom. In N. G Lederman, & S. K Abell (Eds.), Handbook of Research on Science Education Volume II, (pp. 515-541), New York & London: Routledge Taylor & Frieds Group.

Dahl, Ch. D., Wallraven, Ch., Bülthoff, H. H., & Logothetis, N.K. (2009). Humans and Macaques Employ Similar Face-Processing Strategies. Current Biology 24 (19), 509-513.

Furness, P. (2007). A randomized controled trial of the diagnostic accuracy of internet-based telepathology compared with conventional microscopy. Histopathology, 50(2), 266–273.

Jaarsma, T., Jarodzka, H., Nap, M., et al. (2013). Expertise Development under the

Microscope. 17. European Conference on Eye Movements, 11-16. August, Lund, Sweden.

Jäkel, L. (2012). Working with the microscope as a problem solving process. In C. Bruguière, A. Tiberghien, & P. Clément (Eds.), E-Book Proceedings of the ESERA 2011 Conference: Science learning and Citizenship. Part: Pre-service science teacher education, co-ed. D. Psillos, & R. M. Sperandeo, Lyon, France: European Science Education Research Association.

Kastenhofer, K. (2004). Sehen lernen und sichtbar machen. Lehrkultur und

Wissenschaftspraxis Biologie. In S. Böschen, & P. Wehling (Eds.), Wissenschaft zwischen Folgeverantwortung und Nichtwissen. Aktuelle Perspektiven der wissenschaftlichen Forschung. (pp. 91-126.), Wiesbaden: VS Verlag für Sozialwissenschaften.

Korres, A., Ribeiro, S., dos Santos, P., et al. (2014). Didactic and workshop experience in microscopy for high school and college students. In A. Méndez-Vilas (Ed.), Microscopy: advances in scientific research and education, 2(6), (pp. 1137-1144), Badajoz: Formatex.

Mack, D. J., & Ilg, U. J. (2014). The effects of video game play on the characteristics of saccadic eye movements. Vision Res, 102, 26-32.

Mayer, R. E. (2005). Cognitive theory of multimedia learning. In R. E. Mayer (Ed.), The Cambridge Handbook of Multimedia Learning (pp.31-48). Cambridge: University Press.

Merk, M., Knuechel, R., & Perez-Bouza, A. (2010). Web-based virtual microscopy at the RWTH Aachen University: Didactic concept, methods and analysis of acceptance by the students. Annals of Anatomy 192(6), 383–387.

Quiroga, R., & Pedreira, C. (2011). How do we see art: an eye-tracker study. Frontiers in Human Neuroscience, 5(98), 1-9.

Rey, G. D., & Buchwald, F. (2011). The expertise reversal effect: Cognitive load and motivational explanations. Journal of Experimental Psychology, 17(1), 33-48.

Rheinberg, F., Vollmeyer, R., & Engeser, S. (2003). Die Erfassung des Flow-Erlebens. In J. Stiensmeier-Pelster & F. Rheinberg (Eds.), Diagnostik von Motivation und Selbstkonzept (2) (pp. 261-279). Göttingen: Hogrefe.

Romer, D., & Suster, S. (2003). Use of virtual microscopy for didactic live-audience presentation in anatomic pathology. Ann. Diagn. Pathol., 7(1), 67-72.

Scoville, S. & Buskirk, T. (2007). Experimental Comparison of Two Instructional Methods for Teaching Histology: Traditional Microscopy and Virtual Microscopy. Clinical Anatomy 20, 565-570.

Sweller, J., van Merrienboer, J., & Paas, F. (1998). Cognitive architecture and instructional design. Educational Psychology Review, 10, 251-296.

Yarbus, A. L. (1967). Eye movements and vision. New York: Plenum Press.

ARTICULATION OF EVALUATION CRITERIA FOR IMPROVEMENT PRE-SERVICE TEACHERS' ARGUMENT SKILLS

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Abstract: Argument skills are required not only by learners but also by teachers, however it has been reported that teachers' argument skills are at the low level. In this study, we introduced articulating the evaluation criteria for argument to argumentative practices on the matter of the for and against of genetically modified food. The research question is: in what ways does the argumentative practices with the articulation process improve pre-service teachers' argument skills? 77 Japanese pre-service teachers were divided into the experimental condition (37 teachers) and the control condition (40 teachers). In both conditions, they read material about genetically modified food and discussed it with their peers. Then they wrote and revised position papers to justify their own position. While revising, only the pre-service teachers in experimental condition filled out a worksheet on their interpretation (that is, their articulation) of the evaluation criteria. Before and after these argumentative practices, the assessment tasks were carried out on the issue of global warming. To engage in the assessment tasks, the pre-service teachers freely elaborated their arguments on the question sheet, using three pieces of evidence for and three pieces against CO_2 reduction. Based on the Knowledge Integration scoring scheme, we gave score to arguments constructed by pre-service teachers in the assessment tasks. As a result, in the experimental condition, except for "Normativity" in which a ceiling effect was observed, the score significantly improved on all elements from before to after the implementation of the argumentative practices. Furthermore, in the final assessment tasks, for "Evidence in favor of chosen position," "Counter-evidence to evidence against their position," and "Conclusion to overall argument," the experimental condition's score was significantly higher than control condition's score. We conjectured that articulation of evaluation criteria is one of the effective instructional strategies for the improvement of teachers' argument skills.

Keywords: argumentation, socioscientific issues, pre-service teacher education

THEORETICAL FRAMEWORK

Argument skills are required not only by learners but also by teachers, however it has been reported that teachers' argument skills are at the low level (Zohar, 2008). For example, pre-service teachers have found it difficult, in discussing global warming, to describe evidence drawn from concrete data, to cite the reason for their selection of evidence, and to modify the conclusion by adding positions held by their opponents (Yamamoto et al., 2014).

According to preceding studies, in order to improve pre-service teachers' argument skills, argumentative practice (Kaya, 2013) is required; also identified as important have been the laboratory context, which promotes effective inquiry (Ozdem et al., 2013), and meta-level awareness of the use of evidence in discourse (Iordanou & Constantinou, 2014). This study, for the first time, provides a new instructional strategy for the improvement of argument skills by examining the effect of the articulation of evaluation criteria.

Articulation refers to the process of constructing, evaluating, and articulating what has been learned (Quintana et al., 2004). Articulation is thought to promotes reflection and facilitate the deepening of the learner's understanding. In addition, by means of articulation, the learner's understanding will be generalized away from a particular context to other specific contexts (Collins, 2006). If pre-service teachers articulate the evaluation criteria of argument by themselves, it is expected that understanding of the evaluation criteria will deepen and it will become easier to construct and evaluate arguments in other contexts.

PURPOSE OF THE STUDY

In this study, articulating the evaluation criteria for argument is applied to argumentative practices on the matter of the for and against of genetically modified food. Contrasting this experimental condition is a control condition where the articulation process is no applied. The research question of the study is: in what ways does the argumentative practices with the articulation process improve pre-service teachers' argument skills?

RESEARCH DESIGN AND METHODOLOGY

Participants

The participants in this study were Japanese pre-service teachers seeking a primary teacher's qualification. The study used a 1×2 between subjects design. 77 pre-service teachers were assigned to one of two conditions. The number of students in each condition: experimental condition (with articulation, 37 pre-service teachers), control condition (without articulation, 40 pre-service teachers). None of the participants had previously experienced any education specifically on the topic of argument.

Outline of Argumentative Practices

In both conditions, the pre-service teachers first read material that contained basic information about genetic engineering. Then, they read material containing arguments both for and against genetically modified food and discussed it with their peers. Next, they carried out arguments based on their reading. After that, each of them wrote a position paper to justify their own position, and upon receiving evaluation of and feedback on their position papers from the teacher educator, they revised their paper accordingly. While revising, only the pre-service teachers in experimental condition filled out a worksheet on their articulation of the evaluation criteria. Figure 1 shows the curriculum outline.

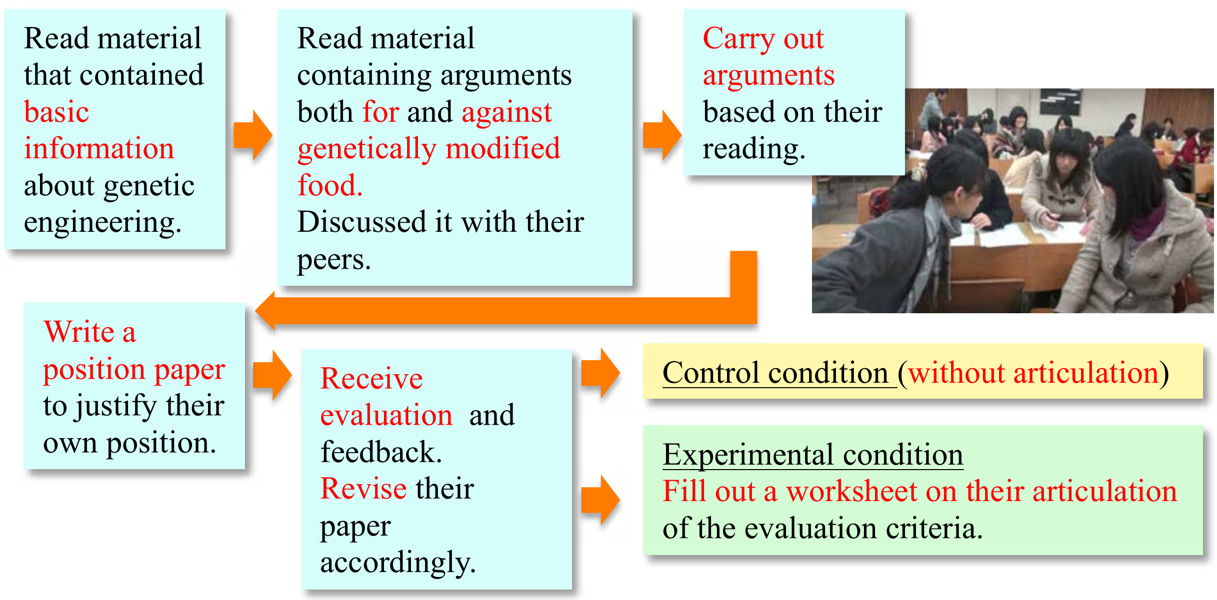

Figure 1. The curriculum outline.

Evaluation Criteria

The Knowledge Integration (KI) scoring scheme developed in Seethaler & Linn (2004) was used as the evaluation criteria for pre-service teacher and as the framework scoring pre-service teachers' argument on the assessment for researchers. With regard to the arguments, a score of 0 was assigned when no writing was done, a 1 was given when some writing was provided, and a 2 was given when the writing provided an elaborate argument presenting "Evidence in favor of chosen position," "Evidence against chosen position," or "Counter-evidence to evidence against chosen position." As for "Normativity," a 0 was given for arguments deemed to be inappropriate, and a 1 was given for appropriate ones. Finally, for "Conclusion to Overall Argument," a 0 was given when no conclusion was provided, a 1 was given when the conclusion was one-sided, a 2 was given when the conclusion contained both positions but also inappropriate evidence, and a 3 was given when the conclusion contained both positions and all evidence used was appropriate.

Assessment Tasks of Argument Skills

The assessment tasks were carried out on the issue of global warming, which was different topic from but same structure as the position papers about genetically modified food. Figure 2 indicates the assessment tasks of argument. The pre-service teachers read three pieces of evidence for and three pieces against CO_2 reduction, and wrote arguments on whether Japan should reduce CO_2 emissions or not. To engage in the assessment tasks, the pre-service teachers freely elaborated their arguments, using the question sheet. The assessment tasks were carried out before and after the argumentative practices, and took twenty minutes. Scoring was carried out by two of the authors independently.

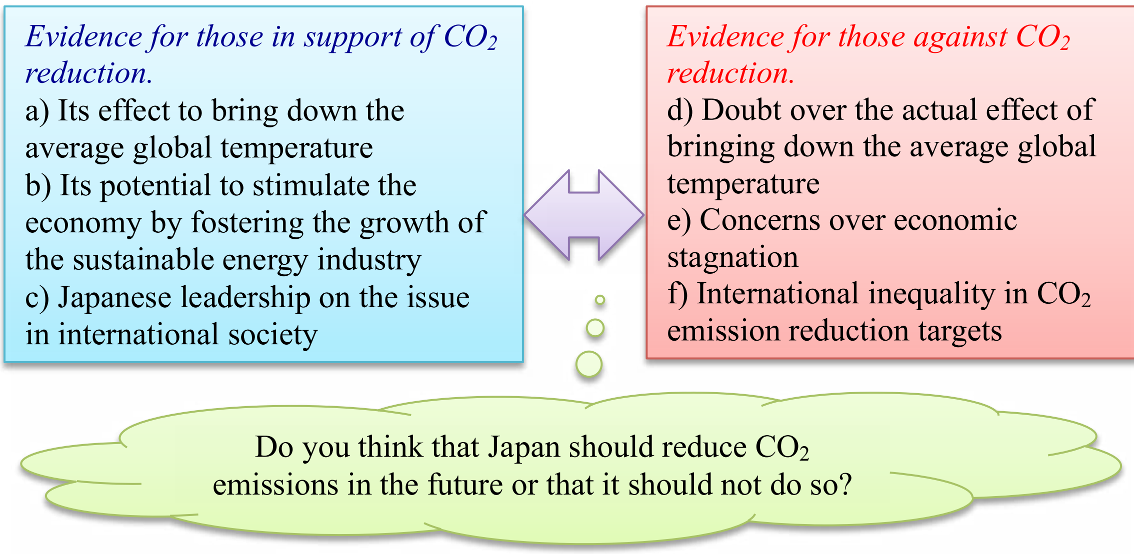

Figure 2. The assessment tasks of argument.

DATA ANALYSIS AND RESEARCH FINDINGS

Figure 3 shows an example of the pre-service teacher's worksheet. On the element "Evidence in favor of chosen position" he understood the criteria for full score, and filled out a worksheet on their articulation of the evaluation criteria. In the assessment tasks, he got full score of the final assessment.

Table 1 shows the number of students achieving each KI score before and after the argumentative practices. Table 2 indicates comparison between initial-final assessment and control-experimental condition. In both conditions, a ceiling effect was observed in "Normativity." Wilcoxon signed-rank test results show that among the pre-service teachers in control condition, the scores improved to a significant degree from before to after the

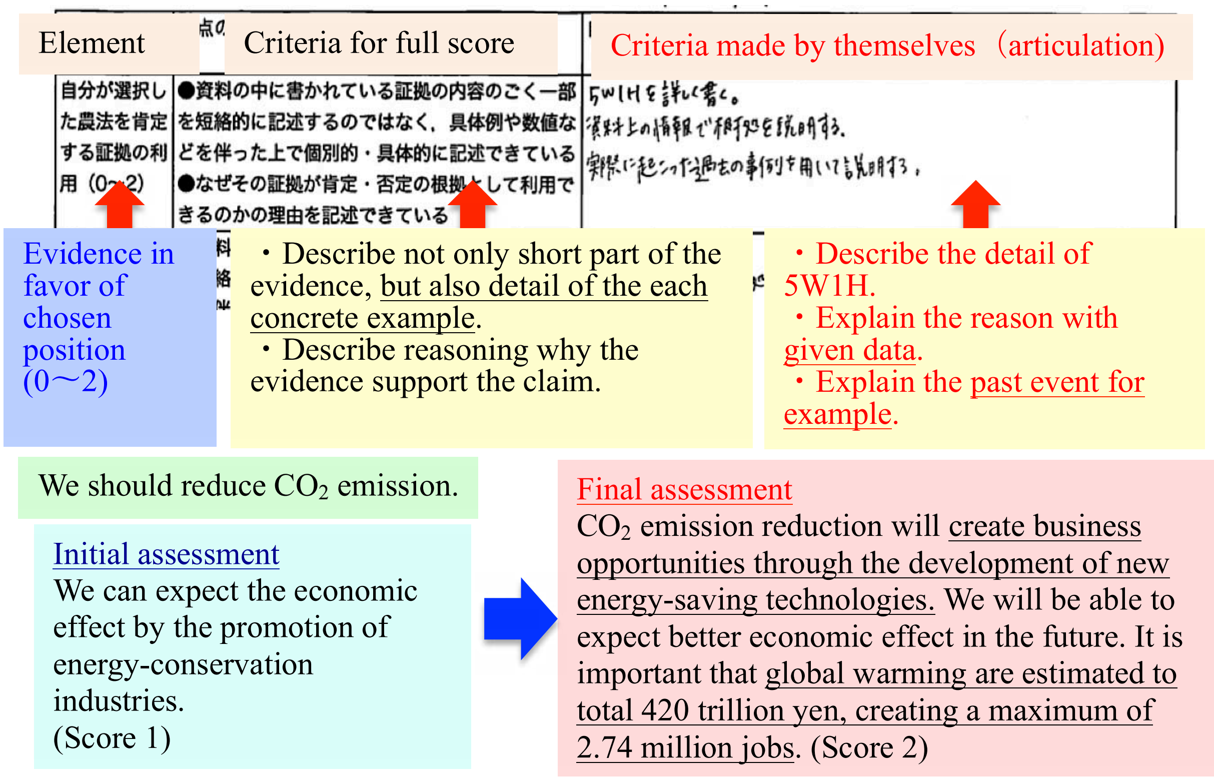

Figure 3. An example of the pre-service teacher's worksheet.

Table 1

Number of Students Achieving Each KI Score

Element of argument	Scores	Control condition: Initial assessment (N=40)	Control condition: Final assessment (N=40)	Experimental condition: Initial assessment (N=37)	Experimental condition: Final assessment (N=37)
Evidence in favor of chosen position	0	14	2	22	0
	1	24	16	13	7
	2	2	22	2	30
Evidence against chosen position	0	8	4	9	1
	1	32	18	27	22
	2	0	18	1	14
Normativity	0	0	0	0	0
	1	40	40	37	37
Counter-evidence to evidence against their position	0	19	17	23	7
	1	18	18	12	24
	2	3	5	2	6
Conclusions to overall argument	0	1	0	1	1
	1	39	28	32	14
	2	0	0	0	0
	3	0	12	4	22

Table 2

Comparison Between Initial-final Assessment and Control-experimental Condition

Element of argument	Between initial-final assessment		Between control-experimental assessment	
	Control condition *Z*	Experimental condition *Z*	Initial assessment *Z*	Final assessment *Z*
Evidence in favor of chosen position	4.40**	5.04**	1.83	2.62**
Evidence against chosen position	3.65**	3.75**	0.27	0.00
Normativity	0.00	0.00	0.00	0.00
Counter-evidence to evidence against their position	0.58	3.42**	1.35	2.04*
Conclusions to overall argument	3.58**	3.80**	1.91	2.67**

Note. *p<.05, **p<.01

argumentative practices (p<.01) except for "Counter-evidence" (*ns*). On the other hand, in the experimental condition, the score significantly improved on all elements from before to after the argumentative practices (p<.01).

Furthermore, the results of the Mann–Whitney U test show no significant difference in score distribution in the initial assessment tasks between the control and experimental conditions (*ns*). However, in the final assessment tasks, except for "Evidence against chosen position" and "Normativity" (*ns*), the experimental condition's score was significantly higher ("Evidence in favor of chosen position" and "Conclusions to overall argument"; p<.01, "Counter-evidence to evidence against their position"; p<.05).

CONCLUSIONS AND IMPLICATIONS

The pre-service teachers in experimental condition showed more improvement in using evidence to describe their own arguments, to argue against the opposite position, and to draw a conclusion after weighing different positions than the pre-service teachers in control condition did. This finding suggests that the participants were able to examine these elements carefully to support their own arguments and apply these skills to a different context. We conjectured that articulation of evaluation criteria is one of the effective instructional strategies for the improvement of teachers' argument skills. The future task is to reveal what kind of articulation improves teachers' argument skills.

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REFERENCES

Collins, A. (2006). Cognitive apprenticeship. In R. K. Sawyer (Ed.), *The cambridge handbook of the learning sciences* (pp.47-60). New York, NY: Cambridge University Press.

Iordanou, C., & Constantinou, C. P. (2014). Developing pre-service teachers' evidence-based argumentation skills on socio-scientific issues. *Learning and Instruction, 34*, 42-57.

Kaya, E. (2013). Argumentation practices in classroom: Pre-service teachers' conceptual understanding of chemical equilibrium. *International Journal of Science Education, 35*, 1139-1158.

Ozdem, Y., Ertepinar, H., Cakiroglu, J., & Erduran, S. (2013). The nature of pre-service science teachers' argumentation in inquiry-oriented laboratory context. *International Journal of Science Education, 35*, 2559-2586.

Quintana, C., Reiser, B. J., Davis, E. A., Krajcik, J., Fretz, E., Duncan, R. G., Kyza, E., Edelson, D., & Soloway, E. (2004). A scaffolding design framework for software to support science inquiry. *The Journal of the Learning Sciences, 13*, 337-386.

Seethaler, S. & Linn, M. (2004). Genetically modified food in perspective: An inquiry-based curriculum to help middle school students make sense of tradeoffs. *International Journal of Science Education, 26,* 1765-1785.

Yamamoto, T., Yamaguchi, E., Muratsu, K., Nakashin, S., & Inagaki, S. (2014). Evaluation of Japanese pre-service teachers' arguments on global warming. In C. P. Constantinou, N. Papadouris, & A. Hadjigeorgiou (Eds.), *E-book Proceedings of the ESERA 2013 conference Part 13,* 62-67.

Zohar, A. (2008). Science teacher education and professional development in argumentation. In S. Erduran, & M. P. Jiménez-Alexandre (Eds.), *Argumentation in science education: Perspectives from classroom-based research* (pp.245-268). Netherlands: Springer.

PRE-SERVICE PRIMARY TEACHERS' BELIEFS OF TEACHING SCIENCE WITH SIMULATIONS

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Abstract: Although the benefits of the use of simulations in science education have been extensively documented, research on pre-service teacher education related to the use of simulations in science teaching remains limited. The aim of this study was to investigate the beliefs of pre-service primary teachers in two teacher training programs of two different universities (n = 36 and n = 18) related to teaching science with simulations. The teachers participated in an intervention where they planned and gave a science lesson where simulations were used. The effect of the two different types of interventions on the beliefs was also studied. The Interconnected Model of Professional Growth by Clarke and Hollingsworth is used as a framework for the effect that the intervention has on the beliefs. The data was collected through post-intervention surveys with open questions. After the both interventions pre-service teachers perceived the simulations' ability to demonstrate otherwise unobservable phenomena and motivate the learners' as their advantages and appropriate use of simulations in relation to the learning goals was seen a challenge. Likewise, all pre-service teachers viewed technological and pedagogical knowledge as important know-how for teachers when teaching with simulations. There were differences in the conceptions after the two interventions, mostly related to the weaknesses of simulations and the teacher know-how needed. These can be explained with the differences between the interventions. The results confirm the impact that external stimuli such as these kinds of interventions have on teachers' beliefs. It is vital to design teacher training for simulations in a way that offers just the right amount of support to enable the future teachers to be able to start teaching science with simulations.

Keywords: Simulations, teacher beliefs, pre-service teachers

INTRODUCTION

Technology and teacher beliefs

The benefits of computer simulations in science teaching have been widely studied during the past 15 years (Rutten, van Joolingen, & van der Veen, 2012). The conclusion from these studies is that the use of computer simulations can enhance science instruction, especially as far as laboratory activities are concerned (Rutten et al., 2012). They have a positive effect on learning, learner attitudes and motivation (Rutten et al., 2012; Smetana & Bell, 2012).

Even though the learning benefits of simulations are accepted, they are perhaps not used to their full extent. The results from the international Trends in International Mathematics and Science Study (TIMMS) from the year 2011 state that on average 25% of the 4th graders who participated in the study were asked to study natural phenomena through simulations at least monthly (Martin, Mullis, Foy, & Stanco, 2012). The lack of computer resources can have an effect on this but also in countries like Finland where 66% of students have access to computers for their science lessons just 15% of the 4th graders were asked to study natural phenomena through simulations at least monthly (Martin et al., 2012).

When looking at factors that affect teachers' use of technology in classrooms, two sets of barriers have been distinguished (Ertmer & Hruskocy, 1999; Ertmer, Ottenbreit-Leftwich, Sadik, Sendurur, & Sendurur, 2012). The *first-order* barriers are external to the teacher and include access to hardware and software, training and support. The *second-order* barriers comprised those that are internal to the teacher and include confidence to use technology, beliefs about student learning and perceived value of technology for their teaching and students' learning. Beliefs link objects and attributes together (Koballa, 1989). An example of a belief would be "Using computers (object) in teaching is beneficial (attribute) for learning". The second-order barriers are thought to pose a larger challenge for technology integration to classrooms (Ertmer & Hruskocy, 1999; Ertmer et al., 2012). Teacher beliefs are seen as vital to consider in order to facilitate technology integration in classrooms (Kim, Kim, Lee, Spector, & DeMeester, 2013). Pre-service teachers' experiences from their teacher training program and beliefs about the usefulness of technology in teaching and learning influence their choice to use technology in teaching (Chen, 2010). The role of pre-service teachers' technological, pedagogical and content knowledge (Koehler & Mishra, 2009; Mishra & Koehler, 2006) on the integration of technology in their teaching has also been studied. The results show that pre-service teachers' self-assessed knowledge related to technology in teaching has a correlation with their self-efficacy beliefs related to technology integration (Abbitt, 2011) and that pre-service teachers' self-assessed technological knowledge is connected to their perception towards integrating simulations into their teaching (Lehtinen, Nieminen, Viiri, 2015).

Literature shows, that in order to develop pre-service teacher training regarding the use of simulations, there is a need to study the beliefs pre-service teachers have on teaching science with simulations. By looking at the role that teacher training has on these beliefs, this training can be further develop to lower the second-order barriers to simulation integration discussed earlier and this way possibly increase the use of simulations in science classrooms.

Theoretical background

The role of teacher knowledge, beliefs and attitudes on their work has been studied from different perspectives. Fullan (1982) viewed that change in teachers' knowledge and beliefs preceded the change in classroom practices. On the other hand, Guskey (1986) modeled teacher change in a way where change in classroom practice preceded the change in teachers' beliefs and attitudes. Clarke and Hollingsworth (2002) formulated their own model of teacher change which was a cyclical process. Their Interconnected Model of Professional Growth is presented in Figure 1.

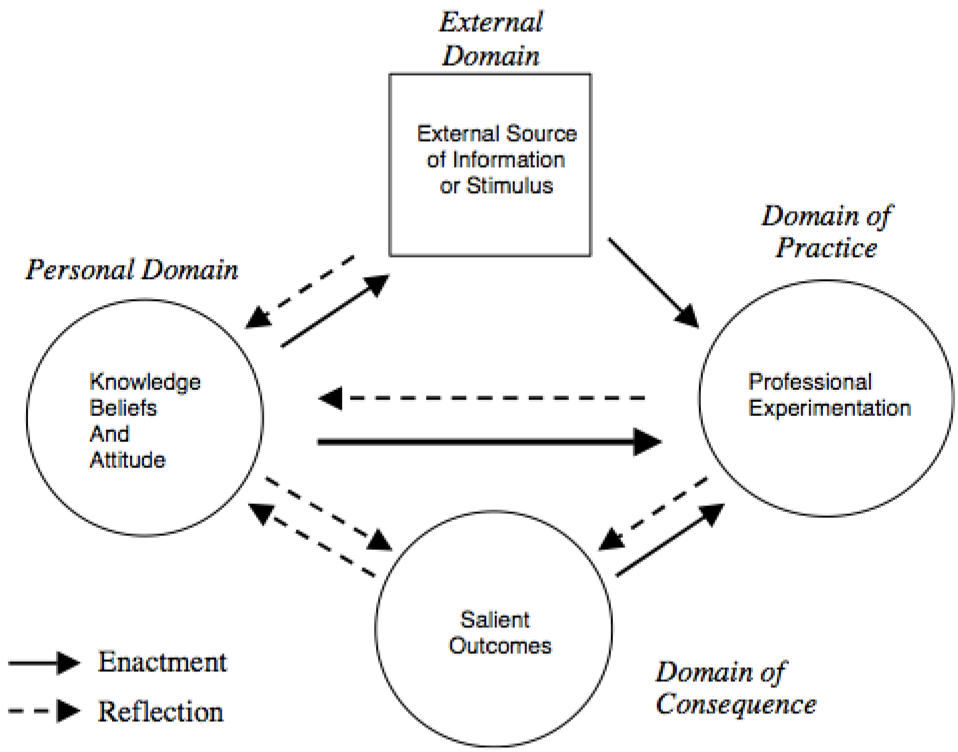

Figure 1. The Interconnected Model of Professional Growth by Clarke and Hollingsworth (2002).

The model states that teacher change occurs through the processes of enactment and reflection between four different domains. These domains are the external domain (information, stimulus or support), the personal domain (knowledge, beliefs and attitudes), the domain of practice (professional experimentation) and the domain of consequence (salient outcomes). The model highlights the effect that external information or stimulus, such as interventions or courses of teacher training programs, have on teachers' beliefs and attitudes and their professional experimentation. Different kinds of stimuli can result in differences in teachers' beliefs and attitudes.

Our study

The aim of this study is to find out what kinds of conceptions do pre-service primary teachers have about teaching science with simulations. An area of interest is also their conception on what kinds of know-how does a teacher need to have in order to teach science with simulations. This reveals if the pre-service teachers' think that teaching with simulations needs e.g. content knowledge or technological knowledge. Also, because the data comes from two different universities, the effect of different external stimuli related to teaching science with simulations on the pre-service teachers' beliefs can be studied according to the Interconnected Model of Professional Growth by Clarke and Hollingsworth (2002). In the discussion section of this paper we aim to explain the possible differences in the beliefs with the content of the interventions.

Our research questions are as follows:

1. What kinds of beliefs do pre-service teachers have about teaching science with simulations after participating in an intervention on the subject?
2. What kinds of teacher know-how do pre-service teachers view as important when teaching science with simulations?

3. What kind of differences are in these beliefs and teacher know-how when the two different interventions are compared?

METHOD

Participants and context

The study was conducted in primary school teacher training programs of two Finnish universities (henceforth University A (UA) and University B (UB)). The pre-service teachers (UA: n = 36, 31 female and 5 male, mean age 24.2; UB: n = 18, 16 female, 2 male, mean age 22.6) were participating in a mandatory science methods course. The pre-service teachers took part in an intervention focused on teaching science with simulations as a part of their course. However, the participation to the study was voluntary i.e., they were free to deny the use of their data for research purposes. In both of the interventions the pre-service teachers had to plan and teach science lesson/lessons in groups of 4 to 5 for primary school pupils. The intervention began with a chance for the pre-service teachers to try out different simulations, mainly from the PhET simulation repository (University of Colorado, 2014). During the planning process, the groups had a chance to present their plans to their peers and to their teacher educators. The lessons for each group were carried out in different schools and to different pupils. The interventions lasted for about 2 months with weekly 90 minute meetings.

The main differences between the interventions are presented in Table 1.

Table 1. The main differences between the two interventions.

University	Assignment	Hardware	Software
UA	Plan an inquiry-based science lesson on a given topic	5 laptops per lesson from the university, were known to work	Were given a PhET simulation
UB	Plan a series of science lessons (6 to 10) from any topic, at some lesson simulations had to be used	From the participating schools, were not tested beforehand	Searched and chose their own simulations

Data collection

The data was collected in both universities few weeks after the lessons through a questionnaire. In this study the analysis focuses on the following open items on the questionnaire: “What kinds of possibilities are involved in using simulations in primary school science teaching?” (96 answers in UA, 45 in UB), “What kinds of weaknesses are involved in using simulations in primary school science teaching?” (77 answers in UA, 30 in UB) and “What kind of know-how does a teacher need in order to use simulations in his/her teaching?” (80 answers in UA, 39 answers in UB). The pre-service teachers could list as many answers to each item as they desired. As background questions, items about the pre-service teachers’ previous experiences with simulations were also included. 1 of the 36 pre-service teachers in UA and 1 of the 18 in UB had had previous experiences with simulations in science teaching. They had used them in their high school science lessons.

Analysis

The answers to the items about the possibilities and weaknesses of simulations were analyzed using thematic analysis following the steps by Braun and Clarke (2006). The data was read multiple times in order to be familiarized with it. Then, initial codes for the answers were generated. These codes were then used to form the initial themes which were in the end defined and named.

The answers in the item on teacher know-how were coded using a pre-determined coding scheme based on the Technological Pedagogical Content Knowledge (TPACK) framework (Koehler & Mishra, 2009; Mishra & Koehler, 2006). The different know-hows listed were coded as either relating to technological knowledge, pedagogical knowledge or content knowledge. These are the main components in the TPACK framework. The coding for the teacher know-how were done by two coders. There was an almost perfect agreement (Landis & Koch, 1977) between the two coders, $\kappa = .913$ (95% CI .851 to .976), $p < .001$. The differences were settled through negotiations. The chi-squared test was used to study the possible differences in the distribution of these three types of know-how between the universities. The alpha level was set at .05.

RESULTS

Possibilities of simulations

Two themes related to the possibilities that simulations bring to science teaching were common to both UA and UB: "demonstrating different phenomena" and "motivating the learners". The theme "benefits for inquiry learning" was identified just in the answers from UA

Simulations' ability to visualize phenomena that are otherwise unobservable using our senses was seen as a possibility when teaching with simulations. Answers like "*making abstract things concrete e.g. forms of energy and conservation of energy* (UA)*"* and *"enabling the observation of phenomena which would otherwise be very hard observe in classrooms* (UB)". Simulations were also seen as visualization tools that support other modes of communication: *"useful tool for demonstrations; supports talk/explanations* (UA)*", "demonstrates theories exceptionally well* (UB)*".*

After teaching for the first time with simulations, the pre-service teachers viewed that the learners were motivated to use the simulations. They felt that simulations enable the learners to have an active role in the classroom *"[simulations] prevent the learners from being passive* (UB)*", "[simulations] inspire to learn* (UB)*".* Simulations were also seen as motivating for the variety in teaching methods they bring: *"[simulations] are motivating and bring variety to the traditional style of learning with paper and pencil* (UA)*".*

The pre-service teachers in UA viewed that simulations allow learners to take responsibility of their own learning: *"inquiry learning: raising questions from the learners themselves* (UA)*", "allows the learners to engage in free inquiry* (UA)*".* Simulations were seen as an effortless learning method to have the learners to engage in inquiry activities: *"(simulations) are an easy way to carry out inquiry teaching* (UA)*".*

Weaknesses of simulations

The theme "appropriateness of simulations for learning" was identified as weakness in both UA as well as UB: "appropriateness of simulations for learning". Only in UA, three additional themes were identified: "need for teacher support", "too few computers" and "the appearance of the simulations". For UB, also three additional themes were identified: "effort of finding simulations", "technical issues of simulations" and "content issues of simulations".

In both universities the pre-service teachers raised the issue that simulations are not always the best tools for learning science : *"someone might learn better by reading a book, the solution to this is to encourage these learners to pick up their books* (UB)*", "are simulations appropriate* *for the subject, this should be taken into account when planning the lessons* (UA)*"*.The pre-service teachers also feared that simulations could be used too much: *"simulations should not be used too much, I feel that they would lose their purpose* (UA)*"*.

In UA, the need to provide teacher support for learning with simulations was seen as an issue with teaching with simulations: *"the use of simulations requires clarifications and questions essential for learning the content in order to make sure learning is happening* (UA)*"*, *"the learners might act without thinking or realizing their actions, teacher guidance is required* (UA)*"*. Some pre-service teachers were also worried about teachers' ability to tend to the learning needs of many small groups: *"the usage of time by the teacher; does he/she have the time to guide and support the development of every learners' thinking* (UA)*"*.

The issue of having too few computers for the learners and the resulting large group sizes per computer was seen as a weakness in UA. The issue was approached both from the viewpoint of learning: *"group working skills do not necessarily develop if just one from the group uses the simulation and the others are just watching; this could result in less learning* (UA)*"* and from the viewpoint of learning environments: *"The computer class is a gloomy environment; is it possible to get enough computers to a normal classroom to keep the number of learners per computer low?* (UA)*"*.

The appearance of simulations was also seen as a weakness of simulations in UA. It was suspected that simulations are too simple or abstract and these could cause issues for learning: *"[simulations] are radical simplifications of complex phenomena; worst case scenario is that they will cause misconceptions* (UA)*"*, *"the content can be misunderstood if the simulation is not concrete enough* (UA)*"*. The appearance of the simulations was also seen as too primitive: *"appearance really tacky in some cases* (UA)*"*, *"some simulations are kind of crappy; old-fashioned and not working so well* (UA)*"*.

In UB, the pre-service teachers mentioned that the effort to find suitable simulations for the topic at had was too time consuming: *"there are not ready-made simulations always available; at least in the beginning it is tremendous amount of work to find or produce simulations* (UB)*"*, *"it is not easy find simulations for all topics* (UB)*"*.

Technical issues with using simulations were seen as a weakness by the pre-service teachers at UB. Some teachers raised the point that teachers' need to have a plan in case something goes wrong: *"the operation of technological devices and simulations is not guaranteed; that is way there should be some kind of alternative plan in case technology fails* (UB)*"*. Also the need to have s specific kind of device was brought up: *"most of the simulations did not work on a Mac; it is possible that the issue was in the user* (UB)*"*, *"the simulations did not work on all devices* (UB)*"*.

The pre-service teachers in UB felt that the content of some simulations is too difficult for the learners: *"simulations can have sections that do not suit learners of that particular age* (UB)*"*, *simulations are aimed for older learners* (UB)*"*. Pre-service teachers were also not satisfied with some simulations as whole: *"simulations can have a lot of extra content that is irrelevant for learning* (UB)*"*.

Teacher know-how needed to teach with simulations

The teacher know-how listed by pre-service teachers was coded for three different categories of teacher knowledge: content knowledge, pedagogical knowledge or technological knowledge. Teacher know-how related to content knowledge included answers such as *"the teacher must know the content in order to use simulations effectively* (UA)*"*, *"knowledge of content; the* *teacher understands what is happening in the simulation and can point out the essential* (UB)*"*. For pedagogical knowledge the teacher know-how listed included *"organizational skill; the teacher must be able to keep the learners focused on the subject and make them avoid unnecessary messing around* (UA)*"*, *"subtle guiding; making good leading questions* (UA)*"*. Know-how related to technological knowledge included *"ability to solve any possible technological issues* (UA)*"*, *"basic level knowledge of technology* (UB)*"*, *"not much else than then the ability to use technology for benefit and to be critical for its use* (UB)*"*. The absolute and relative frequencies for the different categories of teacher know-how and the chi-square test results for their distributions are presented in Table 2. In UA teacher know-how related to pedagogical knowledge was most common and in UB it was teacher know-how related to technological knowledge. A chi-square test of independence was performed to examine the relation between the interventions and views of teacher know-how. The relation between these variables was significant, χ^2 (2, N = 81) = 6.91, p < .03.

Table 2. Pre-service teachers' views of the teacher know-how needed to teach with simulations.

Type of teacher know-how	University A (n=81)		University B (n=42)		Overall (n=123)	
	frequency	relative frequency	frequency	relative frequency	frequency	relative frequency
Content knowledge	17	21.0%	12	28.6%	29	23.6%
Pedagogical knowledge	39	48.1%	10	23.8%	49	39.8%
Technological knowledge	25	30.9%	20	47.6%	45	36.6%

χ^2 = 6.91*

DISCUSSION AND CONCLUSIONS

Results common for both universities

The teachers both in UA and UB felt that possibilities of using simulations in science teaching lie in their ability to demonstrate different phenomena and to motivate students to learn science. Previous research on simulations has acknowledged the possibilities that simulations have regarding learning about phenomena and situations that are otherwise e.g. too slow to observe (van Berkum & de Jong, 1991). The motivational benefits of simulations compared to traditional lectures have also been verified in many studies (Rutten et al., 2012). By participating in this kind of short intervention and teaching a lesson using simulations, the pre-service teachers were able to form beliefs that are empirically valid and in unison with the research literature on the subject.

Regarding the weaknesses of simulation in science teaching, pre-service teachers from both universities felt that simulations are not always useful tools for teaching specific content. Some learners prefer other learning methods and the teacher must pay attention to how using simulations would benefit the learning of any specific content. This conception about simulations in science teaching is shared by the research community. Although some studies find that learning specific content with simulations results in better conceptual learning than traditional hands-on activities (Zacharia, 2007; Zacharia, Olympiou, & Papaevripidou, 2008), other studies find that the best learning results come from combining hands-on activities and simulations (Jaakkola & Nurmi, 2008). Also, the interaction with physical manipulatives is beneficial for learning e.g. the complexity to collect scientific evidence (Zacharia & Constantinou, 2008). Even though the intervention was about using simulations to teach science, the pre-service teachers were able to form a critical belief backed up research literature that simulations are not the best teaching tools for everything in science.

The pre-service teachers saw that teachers need mainly know-how related to pedagogical and technological knowledge when teaching science with simulations. The high number of answers related to technological knowledge implies that the pre-service teachers think about teaching science with simulations to be about the technology per se, not what kinds of possibilities and challenges it imposes on the teachers. The connection between self-assessed technological knowledge and attitude towards simulations has been discovered in previous research (Lehtinen, Nieminen, Viiri, 2015). The role of the teacher in supporting the learners in working with the simulations from a pedagogical, not technological standpoint, is seen as critical for the integration of simulations in science classrooms (Hennessy, Deaney, & Ruthven, 2006; Smetana & Bell, 2012). Maybe through more experience in teaching with simulations the pre-service teachers would gain a better view on the pedagogical teacher know-how needed in teaching with simulations.

Differences in results between the universities

The pre-service teachers in UA were assigned to plan and teach an inquiry-based lesson in which simulations were used. Also the theme “benefits for inquiry learning” was identified in their answers about the possibilities of simulations. Because the assignment in UB did not involve an inquiry-based lesson and a similar theme was not identified from their answers, we feel it is justified to argue that assigning the pre-service teachers to plan and teach an inquiry-based lesson affected their view on the possibilities of simulations.

Regarding the weaknesses of simulations, in UB the pre-service teachers felt that the effort to find the simulations to use was a weakness of using simulations alongside with technical issues and issues with the content of the simulations. In UB the pre-service teachers could choose the topics of their lessons to be taught and also the simulations that they used in them. They also did not have a chance to try out the actual hardware they used in their lessons beforehand. This was in contrast with UA, where they pre-service teachers were given a simulation to use and a topic to plan the lesson about. They also could use hardware from the university itself which was known to work with the simulations. We argue that the weaknesses of simulations identified only in UB and not in UA can also be explained with differences in the interventions. It was the first time using simulations for almost every pre-service teacher from UB. That means that they had for the first time look for these simulations from the internet and other sources. This would explain the theme identified weakness “effort of finding simulations”. They also had to rely on their own, most probably quite limited, experience in teaching science to choose the proper topic and simulation for the intended age group of the learners. It is possible that they chose too difficult simulations for the grade they were teaching in and thus felt that there were issues with the content of the simulations. Some of them explicitly mentioned the content of the simulations being too difficult for the learners. The fact that the pre-service teachers in UB were not able to tests their simulations on the schools’ hardware before teaching the lesson and the fact that the theme “technical issues of simulations” was identified in their answers implies that at least some of them experienced some technical difficulties in using the simulations.

For the teacher know-how needed to teach science with technology there was a statistically significant difference in the distribution of the types of teacher know-how between the two universities. The pre-service in teachers in UB viewed the teacher know-how needed as more relating to technological knowledge and less to pedagogical knowledge than the pre-service teachers in UA. The possible technological difficulties that the teachers in UB experienced can explain this. In order to teach with simulations and to think about pedagogical factors affecting their use, the simulations need to function technically. If the pre-service teachers in UB were faced with technological issues when using the simulations, they were more focused in getting them to work than in the actual teaching. The experience of having to deal with technological issues using simulations could affect their perception of the needed teacher know-how when using simulations.

Possible limitations

The results of this study are generalizable to the population of pre-service primary teachers but as shown in this paper the differences in these types of interventions affect the pre-service teachers' beliefs. Following another kind of intervention the beliefs could be different. The data was collected through questionnaire items that were narrowed down. A more open type of data e.g. interviews could have brought an extra perspective to the analysis.

Conclusions

The conclusions of this study support the Interconnected Model of Professional Change; external stimulus (in this case the simulation intervention) has an effect of pre-service teachers' beliefs. In this study, this was most evident in the perceived weaknesses of simulations and on the teacher know-how needed to teach science with simulations.

What does this mean for teacher education related to teaching science with simulations? Because the connection of beliefs related to technology and successful technology integration in classrooms has been uncovered in recent research (Ertmer et al., 2012; Kim et al., 2013), attention to them must be paid in order to efficiently train future science teachers. This study shows the importance of carefully designing teacher training relating to the educational uses of technology. Ideally, the pre-service teachers would have a true and correct perception of their future work as teachers after finishing their teacher training. When teaching with simulations is concerned, that work includes some effort to find and choose fitting simulations for the topics to be taught with simulations. Also sometimes there can be technical difficulties when using simulations, as with all technology. This study shows that if pre-service teachers are faced with these situations as a part of their teacher training, it affects their beliefs related to teaching with simulations. After graduating, if a teacher beliefs that using simulations is hard work and there might be technical problems with using them, she/he might decide to not use simulations at all. Research shows that even if teachers are aware of the learning benefits of technology, their beliefs about technology can still affect their technology integration practices (Ertmer, 2005). Incremental supports are needed (Kim et al., 2013) throughout teacher training to facilitate technology integration in education and the technological confidence of pre-service teachers should be increased as a part of pre-service teacher education (Ertmer, 2005). It might be difficult to find the right balance between giving too much and too little support for pre-service teachers in teaching with simulations but it is something that future research could strive for.

REFERENCES

Abbitt, J. T. (2011). An investigation of the relationship between self-efficacy beliefs about technology integration and technological pedagogical content knowledge (TPACK) among preservice teachers. *Journal of Digital Learning in Teacher Education, 27*(4), 134-143.

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology, 3*(2), 77-101.

Chen, R. (2010). Investigating models for preservice teachers' use of technology to support student-centered learning. *Computers & Education, 55*(1), 32-42.

Clarke, D., & Hollingsworth, H. (2002). Elaborating a model of teacher professional growth. *Teaching and Teacher Education, 18*(8), 947-967.
Ertmer, P. A. (2005). Teacher pedagogical beliefs: The final frontier in our quest for technology integration? *Educational Technology Research and Development, 53*(4), 25-39.
Ertmer, P. A., & Hruskocy, C. (1999). Impacts of a university-elementary school partnership designed to support technology integration. *Educational Technology Research and Development, 47*(1), 81-96.
Ertmer, P. A., Ottenbreit-Leftwich, A. T., Sadik, O., Sendurur, E., & Sendurur, P. (2012). Teacher beliefs and technology integration practices: A critical relationship. *Computers & Education*, *59*(2), 423-435.
Fullan, M. (1982). *The meaning of educational change*. New York: Teachers College Press.
Guskey, T. R. (1986). Staff development and the process of teacher change. *Educational Researcher*, *15*(5), 5-12.
Hennessy, S., Deaney, R., & Ruthven, K. (2006). Situated expertise in integrating use of multimedia simulation into secondary science teaching. *International Journal of Science Education*, *28*(7), 701-732.
Jaakkola, T., & Nurmi, S. (2008). Fostering elementary school students' understanding of simple electricity by combining simulation and laboratory activities. *Journal of Computer Assisted Learning, 24*(4), 271-283.
Kim, C., Kim, M. K., Lee, C., Spector, J. M., & DeMeester, K. (2013). Teacher beliefs and technology integration. *Teaching and Teacher Education*, *29*, 76-85.
Koballa, T. R. J. (1989). *Changing and measuring attitudes in the science classroom*. Athens, GA: The University of Georgia: The National Association for Science Teaching.
Koehler, M., & Mishra, P. (2009). What is technological pedagogical content knowledge (TPACK)? *Contemporary Issues in Technology and Teacher Education, 9*(1), 60-70.
Landis, J. R., & Koch, G. G. (1977). The measurement of observer agreement for categorical data. *Biometrics,* 159-174.
Lehtinen A., Nieminen P., Viiri J., (2015) *Pre-service teachers' TPACK beliefs and attitudes toward simulations.* Manuscript submitted for publication.
Martin, M. O., Mullis, I. V. S., Foy, P., & Stanco, G. M. (2012). *TIMMS 2011 international results in science*. Chestnut Hill, MA, USA and Amsterdam, the Netherlands: TIMMS & PIRLS International Study Center and International Association for the Evaluation of Educational Achievement.
Mishra, P., & Koehler, M. (2006). Technological pedagogical content knowledge: A framework for teacher knowledge. *The Teachers College Record*, *108*(6), 1017-1054.
Rutten, N., van Joolingen, W., & van der Veen, J. (2012). The learning effects of computer simulations in science education. *Computers & Education*, *58*(1), 136-153.
Smetana, L. K., & Bell, R. L. (2012). Computer simulations to support science instruction and learning: A critical review of the literature. *International Journal of Science Education, 34*(9), 1337-1370.
University of Colorado. (2014). PhET simulations. Retrieved from http://phet.colorado.edu/en/simulations/
van Berkum, J., & de Jong, T. (1991). Instructional environments for simulations. *Education and Computing*, *6*(3), 305-358.
Zacharia, Z. (2007). Comparing and combining real and virtual experimentation: An effort to enhance students' conceptual understanding of electric circuits. *Journal of Computer Assisted Learning*, *23*(2), 120-132.
Zacharia, Z., & Constantinou, C. P. (2008). Comparing the influence of physical and virtual manipulatives in the context of the physics by inquiry curriculum: The case of undergraduate students' conceptual understanding of heat and temperature. *American Journal of Physics*, *76*(4), 425-430.

Zacharia, Z., Olympiou, G., & Papaevripidou, M. (2008). Effects of experimenting with physical and virtual manipulatives on students' conceptual understanding in heat and temperature. *Journal of Research in Science Teaching, 45*(9), 1021-1035.

PRE-SERVICE PRIMARY TEACHERS' UNDERSTANDING OF FERMENTATION: THE "LAB-BREWED" BEER PROJECT

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Abstract: This work presents a laboratory module that was given in a compulsory course on Natural Sciences in the degree of Primary Education. The research examined the prior knowledge and learning outcomes on microbiology, and particularly, the chemical changes occurring during a fermentation process. The module was presented as a little project where the laboratory group collaboratively produced their own beer. The students performed simple experiments, easily applicable in a primary school setting, in order to understand the biological process and the chemical transformations occurring during fermentation. The assessment of the students' prior knowledge showed that students lacked scientific knowledge on microorganism taxonomy, only a few of them could mention names of widely known microorganisms, and could not explain the fermentation process. Through experiments in which variables were controlled and compared, students also learned to apply the scientific method and modeled the carbon flux during fermentation. This particular concept was shown to be better understood after the implementation of the module.

Keywords: microbiology, yeasts, biology education

INTRODUCTION

Microbiology in teacher education programs offers a broad spectrum of activities that can help building students' knowledge of science topics along with understanding aspects related to the nature of science. Moreover, many processes of every day's life can be easily interconnected by the fact that microorganisms exist and take part in them, which helps to contextualize the topics under study (Merkel, 2012), and make connections with other disciplines, such as chemistry, health sciences or taxonomy (Izquierdo, 2012). A close inspection of the 14 principles and big ideas of science that should underpin the science education of all students throughout their schooling shows that at least four of them are related to living organisms and can be approached through microbiology, such as: "7-Organisms are organized on a cellular basis; 8-Organisms require a supply of energy and materials for which they are often dependent on or in competition with other organisms; 13-The knowledge produced by science is used in some technologies to create products to serve human ends; and 14-Applications of science often have ethical, social, economic and political implications" (Harlen, 2010). This is in agreement with a work document by the American Association for Microbiology (ASM) (Merkel, 2012), which outlines basic principles about microbiology that should be taught in introductory microbiology courses.

These principles could easily be applied with our students, pre-service primary teachers, which should acquire a basic but solid conceptual and procedural knowledge on Biology (including Microbiology). In fact, it has been shown that pre-service and in-service primary teachers, tend to hold a simplified view of microorganisms in which they usually relate their microscopic size with metabolic simplicity (Hilge, 2001), and focus only on the infectious agents, which can reinforce a negative image of microorganisms. Hence, there is a need to include microbiology in the science curricula of teacher training degrees while overcoming constraints such as program limitations or lack of teacher expertise (Byrne & Grace, 2010; Jones, 2011). In fact, another study by Jones & Rua (2006) alerted that “What may be problematic is the lack of knowledge that elementary and in some cases middle school teachers hold related to microorganisms. (…) Elementary teachers hold knowledge that is only slightly greater than that of their students. If science educators are to foster a more complete conceptual framework of microorganisms it may be beneficial to begin with more extensive teacher preparation in science”.

Table 1 shows the more relevant ideas extracted from the ASM document (Merkel, 2012) and that are in agreement with the curricular design for primary education of the autonomous region of the Basque Country (Basque Goverment, 2007) in Spain.

Table 1. Curricular guidelines for introductory Microbiology that can be applied in pre-service primary teacher training[a]

KEY MICROBIOLOGY CONCEPTS	
Cell Structure and Function	• The structure and function of microorganisms have been revealed by the use of microscopy (including bright-field, phase-contrast, fluorescence and electron microscopy). • While microscopic eukaryotes (for example, fungi, protozoa and algae) carry out some of the same processes as bacteria, many of the cellular properties are fundamentally different.
Metabolic pathways	• The survival and growth of any microorganism in a given environment depends on its metabolic characteristics.
Microbial systems	• Microorganisms are ubiquitous and live in diverse and dynamic ecosystems. • Microorganisms and their environment interact with and modify each other. • Microorganisms, cellular and viral, can interact with both human and non-human hosts in beneficial, neutral, or detrimental ways.

Table 1. (*Continued)*

Impact of microorganisms	• Microbes are essential for life as we know it and the processes that support life (e.g. in biogeochemical cycles and plant and/or animal microflora) • Humans utilize and harness microbes and their products. • Because the true diversity of microbial life is largely unknown, its effects and potential benefits have not been fully explored.
COMPETENCES FOR SCIENTIFIC THINKING AND LABORATORY SKILLS	
Ability to apply the process of science	• Demonstrate an ability to formulate hypotheses and design experiments based on the scientific method
Ability to use quantitative reasoning	• Use mathematical reasoning and graphic skills to solve problems in microbiology
Laboratory skills	• Use appropriate microbiological lab materials and methods • Practice safe microbiology, using appropriate protective and emergency procedures

[a]Adapted from Merkel (2012).

The curricular framework presented here and the widespread state of affairs regarding the scarcity of microbiology in the primary curriculum, guided the design of a laboratory module on microbiology for pre-service primary teachers and a test to evaluate, pre- and post-implementation, concepts related to fermentation. The limited number of studies assessing students' ideas on microorganisms (Byrne & Grace, 2010; Harms, 2002), also justified the need to assess student's prior ideas about microorganisms and fermentation, which prompted the design of two open-ended questionnaires and written exercises before and after the laboratory module.

Another methodological framework that was taken into account in this work was Project Based Learning (Johnson, Johnson, & Smith, 1991), in the sense that active teaching methodologies that are centered on the students and focus on the development of professional competences, should contribute to improve students' learning outcomes. Our university is driving this paradigm shift in line with other universities of the European Higher Education Area and there are many examples, including courses in teacher-training degrees, where different modules have been transformed to follow this approach (Garmendia, Barragués, Zuza, & Guisasola, 2014). Within the context presented in this paper, the authors thought that a starting point could be to contextualize the project around yeasts and brewing beer.

Key Objectives

- To design and implement a laboratory module which introduces microbiology topics including a fermentation process.
- To identify initial student's ideas about microbes and fermentation through two open-ended questionnaires
- To identify the knowledge gain on microbes and fermentation after the implementation of the laboratory module through a written exercise.

METHOD

Participants and design of the laboratory sessions

The module consisted on four laboratory sessions that lasted 2 hours each. During the 2012-2013 year the design of the practicals was tested and we fine-tuned the pre- and post-questionnaires that were administered in the 2013-2014 academic year, where a total of 104 students took part. The data presented in this work correspond to this academic year. First, students were asked to complete an individual questionnaire that aimed to detect the students' knowledge on microbe types, their habitat and examples of harmful and beneficial microorganisms (Table 2). After collecting the questionnaires, and discussing their ideas, the project of producing beer was presented and they were also asked to answer a second questionnaire focused on yeasts and their functions (Table 3). In the following session the students carried out two experiments to observe yeasts at work, one involving the release of carbon dioxide into a balloon (Symington, 2010) and another that assessed the effect of sugar on the rate of growth of a mix of flour, yeast and water (McNulty, 2009). The following laboratory sessions consisted on the preparation of beer following a brewing kit protocol and the observation of fungal structures from rotten food under the microscope. In the final session, the students completed the post-intervention questionnaire.

Data collection and analysis

Data collection took place during a regular lecture by all authors, and students were asked to respond individually, in writing. Participant responses were analyzed and distributed into categories that reflected different levels of reasoning. These categories emerged from the data, and if necessary, new ones were introduced. A subset portion of the data was assessed independently by the first and second author in order to build a common understanding on how to describe the data. Once the categorization scheme was established, the first author applied this scheme to the rest of the data. Frequency distributions of each category were calculated for each question. To assess whether the implementation had an effect on the students' learning process, the frequency of responses and a Chi-square test was calculated between two pre- and post-implementation questions: “Why is yogurt acid?” and “What is the origin of the carbon from the released CO_2 during a fermentation?".

RESULTS AND DISCUSSION

Questionnaire #1 pre-implementation: What is a microbe? And a germ?

Table 2 shows the emerged categories from the first questionnaire, which aimed to evaluate students' ideas about microbes and their habitat. The results show that our students share a limited or superficial understanding of what a microbe is, mentioning that it is "very small in size" or "microscopic" (51 %, question 1, Table 2) but failed to give taxonomic categories or specific examples of microbes, which were given only in 12.5 % of the cases (Table 2). For example, names such as *Escherichia coli, Salmonella* spp. and *Lactobacillus casei* were mentioned only six times. We also asked them to describe a germ (question 2, Table 2), and in 50 % of the cases the answers were assigned to the category of "a disease-causing infectious agent". Jones & Rua (2006) showed a similar result in a study performed with different collectives, including junior students, teachers and medical professionals.

Regarding microbes' habitat, most of the answers (63 %), associated an ubiquitous presence of microorganisms, as shown in previous studies (Jones & Rua, 2006; Simonneaux, 2000). However, nearly a third of the answers associated microbes' habitat mainly with organic matter or living organisms (27 %, question 3, Table 2), which could suggest that they pictured a role of microorganisms basically in decomposing organic matter as shown previously (Hilge, 2001; Simonneaux, 2000). In fact, Hilge (2001) found a relationship between a limited view of metabolic versatility in microorganisms and the fact that they are microscopic and that some of them are unicellular. She keeps on arguing that historically this has been also presented in scientific sources, although the trend in modern textbooks is to oppose morphological simplicity to metabolic versatility (Hilge, 2001; Merkel, 2012).

In order to detect whether students could identify different roles or functions in nature, we asked them to describe examples of microbes and what they do. As shown in Table 2, the proportion of students giving examples (both detrimental and beneficial) was scarce. Some of the examples that appeared in questions 4 and 5 include the description of disease-causing agents, mention the presence of beneficial microorganisms that boost our immune system, or those involved in fermented products (25 %, question 5, Table 2). A similar result was described by Jones & Rua (2006), who stated that when prompted, students could acknowledge the presence of beneficial organisms, but many could not give any specific example or mechanism by which they were beneficial. In open discussions after completing the questionnaires students were encouraged to draw examples of beneficial microorganisms from what they saw in the media, and as Byrne & Grace (2010) observed, gut micro-flora and yogurts emerged as the most common examples.

Questionnaire #2 pre-implementation: What is a fermented product? And what is the process of fermentation?

Table 3 shows the percentage of responses in the emerged categories for the questions about yeasts and fermentation. As expected, most of the students (68 %) could give at least three examples of fermented products, being wine, beer, bread or yogurt,the most mentioned examples. However, no specific names of microorganisms involved in these processes were mentioned. It is noteworthy to stress that the pre-service teachers in this study held conceptions similar to 11 years-old students (Byrne & Grace, 2010). The fact that our students could not establish the differences between bacteria and yeasts, or yeasts and multicellular fungi, prompted a revision session on the classification of life, starting with the five kingdom classification (Whittaker, 1969), still predominant in our school system, and including revisions to this model, such as the Three Domains of Life (Woese, Kandler, & Wheelis, 1990) (data not shown).

Nevertheless, our main interest lay on their understanding of the fermentation process. As shown in Table 3, most of the students had difficulties describing the source of energy during fermentation or its chemical reaction (82 %, question 2, Table 3). Interestingly, the topic of fermentation in yeasts and brewing or baking was rated by novice biology university students as difficulty-posing (Bahar, Johnstone, & Hansell, 1999). We phrased another question related to the chemistry of fermentation by asking why a yogurt is acid or wine alcoholic, and only a 9 % was able to describe the transformation of sugars into acid or alcohol (question 3, Table 3). This is not a trivial matter, and other studies pointed that even freshmen students in science degrees, such as biology or chemistry, have difficulties describing cellular respiration, chemical reactions or, as in our study, the fermentation reaction (Ahtee & Varjola, 1998; Songer & Mintzes, 1994). For example, Songer & Mintzes (1994) described that biology novice college students used the notion that CO_2 is used instead of O_2 in fermentation reactions and did not recognize yeasts as a living organism. Therefore, it is not surprising that our students, which in general do not have a strong background in science from their secondary education (Oliva-Martínez & Acevedo-Díaz, 2005) face difficulties describing the agents, and the process of fermentation.

Table 2. Questionnaire #1 pre-implementation and categorisation of participants' responses[a]; n= 96

Questions (1-5)	Answers (%)
1. What is a microbe? What are the most common types of microbe?	
She mentions 'microscopic' and at least one of the four types (virus, bacteria, fungi, protist)	12.5
She mentions 'microscopic' but does not mention any type	51
Not answered or not appropriate	35
2. What is a germ?	
It is an infectious disease-causing agent	51
Not answered or not appropriate	49
3. Where can we find microbes?	
Everywhere	62.5
In living organisms or organic matter	27.1
Not answered or not appropriate	9.4
4. Give examples of microbes	
At least two examples	19.8
Only one example	15.6
Not answered	64.6
5. Did you mention any example of beneficial microbes? If not, could you mention any?	
At least two examples	3.1
Only one example	21.9
Not answered or not appropriate	75

[a]These questions were adapted from the e-bug junior pack (McNulty, 2009)

Table 3. Questionnaire #2 pre-implementation and categorisation of participants' responses; n=101

Questions (1-3)	Answers (%)
1. Yeasts are responsible to ferment some products. Give at least 3 examples of fermented products	
At least three examples	68.3
One or two examples	27.7
Not answered	4
2. Where do yeasts get their energy from? Do you know the chemical reaction during fermentation?[a]	
From sugars and describes the reactions in her own words	3.0
From sugars but she cannot describe the reaction	14.9
Not answered or not appropriate	82.1
3. Do you know why a yogurt is acid[a] or wine is alcoholic?	
Conversion from lactose to lactic acid or sugar/glucose/fructose to alcohol is mentioned	8.9
Glucose is mentioned, but does not know the reaction, more general terms like nutrition are mentioned	8.9
Not answered or not appropriate	82.2

[a]The responses to these questions were compared to the responses to the questions in the post-test (Table 4)

Questionnaire post-implementation

As described in methods, the students performed several experiments to understand the process of fermentation, examined fungal structures, received supporting information about taxonomy, fermentation and respiration and produced their own beer following a prepared malt extract kit. At the end of the module, students performed a test to evaluate their learning. In this study, we will focus on the results of two questions ("Why is yogurt acidic?" and "When you make beer, where does the carbon in alcohol and carbon dioxide come from?") that aimed to evaluate whether the students were able to explain some processes occurring during fermentation based on the concepts and procedures learned during the practicals (Table 4). Regarding the first question, the percentage of correct answers (conversion of lactose into lactic acid), increased from 17.9 % to 30.4 % (Figure 1A). Regarding the second question, which aimed to ascertain whether the carbon flux during fermentation was understood, the percentage of correct answers (from the sugars in malt), increased from 17.8 % to 28.4 % (Figure 1B). As shown in Figure 1, a tendency is observed towards the increase of correct answers and a decrease in incorrect answers, although such differences between pre- and post- tests were not statistically significant. Nevertheless, this could be explained by the fact that still, most of the students gave inaccurate responses, which reduces the sample size for the category of correct answers. Regarding the carbon flux question (Figure 1B), another explanation for the non-statistically significant improvement, could be that the conceptual understanding of the process was probed through non-identical questions in the pre- and post-intervention questionnaires.

Table 4. Results of the categorisation of participants' responses to post-implementation questions, n = 56

Questions (1-2)	Answers (%)
1. Why is yogurt acidic?	
Lactose is converted to lactic acid	30.4
Not answered or not appropriate	69.6
2. When you make beer, where does the carbon in alcohol and carbon dioxide come from?	
From the sugars in malt	28.4
Not appropriate	62.5

CONCLUSIONS

The main rationale of this research was to identify students' ideas and knowledge gap in microbiology concepts in pre-service primary teachers, and to examine whether by studying microbiological processes from everyday situations, the students could also understand and make connections with basic biological processes. In agreement with previous studies performed with secondary students, we observed that our students have a basic understanding of what a microbe is but failed to give examples and specific names drawn from their everyday experience. Since microbes are usually associated with the term germ, we expected more names of bacterial or viral diseases, but it was not the case. Regarding beneficial microorganisms, only through guided discussion, did some examples emerge, such as those usually depicted in TV advertisements. Although it is not the scope of this paper, these results themselves justify the need to include more instruction on basic microbiology topics in our Primary Education degrees.

Regarding the process of fermentation, the students were aware of the role of yeasts or lactic bacteria in fermenting products, but it was difficult for them to grasp the notion of chemical change during the process (Figure 1A). Rather than focusing our evaluation on taxonomic information or memorization of full scientific names, we focused our attention on the process of nutrition in yeasts. Our results show that, through hands-on experimental activities and by monitoring the progress of their own fermented product, the carbon flux during fermentation was better understood. Of equal importance is the fact that by performing easy to export classroom experiments, the students acquired pedagogical tools. Moreover, we believe that the fact that they carried out a small project, helped them to contextualize the fermentation model. In future studies, we aim to compare interventions in which different classroom groups could prepare different fermented products, including a control in which only classroom experiments are performed (without final product). The results from the post-intervention questionnaires and further feedback and interviews on students will help us to inform on the validity of this approach. We also aim to prepare identical pre- and post-questionnaires to compare systematically the knowledge gain of our students in this topic in a quantitative way.

Finally, since the students are pre-service teachers, a further step should be to mobilize this learning into an hypothetic classroom settings, suggesting suitable fermented products for primary school children, and therefore performing a didactic transposition (Ogborn, 1996). Although this last step was not fully evaluated in this module, we are aware that among microbiology topics, yeasts and their fermented products are covered in many classroom materials (Harms, 2002; Izquierdo, 2012; Lecky et al., 2011; Lewis, 2012; Symington, 2010; Thiel, 1999) and this could be a starting point to help our students to inform their own teaching.

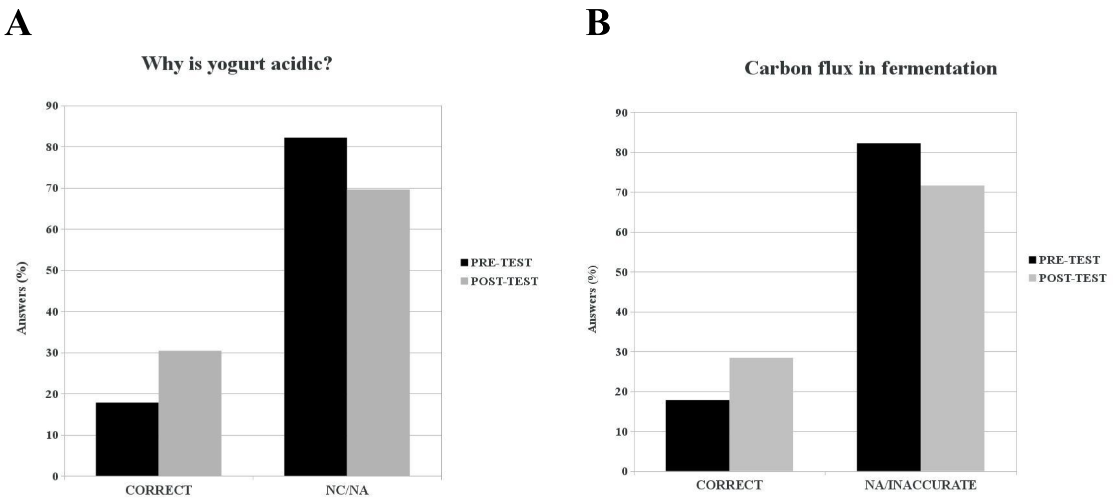

Figure 1. Frequency distributions of correct and incorrect answers to two pre- and post-implementation questions. Black bars show the percentage of correct and inaccurate answers in the pre-test and grey bars show the percentage of correct and inaccurate answers in the post-test to the following questions: A: "Why is yogurt acidic?" and B: "When you make beer, where does the carbon in alcohol and carbon dioxide come from?". A Pearson's Chi-square test for independence was performed for pre- and post-test comparisons (A: n= 56; $\chi2$ = 3.2678; p =0.071; B: $\chi2$ = 3.2678; p = 0.073; n=46).

REFERENCES

Ahtee, M., & Varjola, I. (1998). Students' understanding of chemical reaction. *International Journal of Science Education*, *20*(3), 305–316.

Bahar, M., Johnstone, H., & Hansell, H. (1999). Revisiting learning difficulties in biology. *Journal of Biological Education*, *33*(2), 84–86.

Basque Goverment. (2007, April 26). Decreto 175/2007 por el que se establece el curriculum de la Educación Básica y se implanta en la Comunidad Autónoma del País Vasco. Retrieved December 14, 2015, from http://www.hezkuntza.ejgv.euskadi.eus/r43-2459/es/contenidos/informacion/dif10_curriculum_berria/es_5495/f10_c.html

Byrne, J., & Grace, M. (2010). Using a Concept Mapping Tool with a Photograph Association Technique (CoMPAT) to Elicit Children's Ideas about Microbial Activity. *International Journal of Science Education*, *32*(4), 479–500.

Garmendia, M., Barragués, I., Zuza, K., & Guisasola, J. (2014). Proyecto de formación del profesorado universitario de Ciencias, Matemáticas y Tecnología, en las metodologías de Aprendizaje Basado en Problemas y Proyectos. *Enseñanza de las Ciencias*, *32*(2), 113–129.

Harlen, W. (Ed.). (2010). *Principles and big ideas of science education*. Hatfield, Herts.: Association for Science Education.

Harms, U. (2002). Biotechnology Education in Schools. *Electronic Journal of Biotechnology*, *5*(3), 5–6.

Hilge, C. (2001). Using Everyday and Scientific Conceptions for Developing Guidelines of Teaching Microbiology. In H. Behrendt, H. Dahncke, R. Duit, W. Gräber, M. Komorek, A. Kross, & P. Reiska (Eds.), *Research in Science Education - Past, Present, and Future* (pp. 253–258). Springer Netherlands.

Izquierdo, M. (2012). El impulso lo dan las células. In *Química en infantil y primaria. Una nueva mirada* (pp. 75–103). Barcelona: Graó.

Johnson, W., Johnson, T., & Smith, A. (1991). *Active Learning: Cooperation in the College Classroom*. Edina, MN: Interaction Book Company.

Jones, G., & Rua, J. (2006). Conceptions of germs: expert to novice understandings of microorganisms. *Electronic Journal of Science Education*, *10*(3).

Jones, N. (2011). *Investigating nitrate-dependent humic substance oxidation and in-service K-12 teachers' understanding of microbiology*. Retrieved from http://opensiuc.lib.siu.edu/dissertations/385/

Lecky, M., McNulty, M., Adriaenssens, N., Koprivova, T., Holt, J., Touboul, P., … Noer, M. (2011). What are school children in Europe being taught about hygiene and antibiotic use? *Journal of Antimicrobial Chemotherapy*, *66*(Supplement 5), v13–v21.

Lewis, D. (2012). Bread-making: teaching science in primary school. *Science in School*, (23), 33–37.

McNulty, M. (2009). e-bug. Introduction to microbes. European Commission. Retrieved from http://www.e-bug.eu/lang_sp/primary_pack/downloads/Spain%20Junior%20Complete%20Pack.pdf

Merkel, S. (2012). The Development of Curricular Guidelines for Introductory Microbiology that Focus on Understanding. *Journal of Microbiology & Biology Education*, *13*(1).

Ogborn, J. (1996). *Explaining Science in the Classroom*. McGraw-Hill Education (UK).

Oliva-Martínez, J, & Acevedo-Díaz, J. (2005). La enseñanza de las ciencias en primaria y secundaria hoy. algunas propuestas de futuro. *Revista Eureka sobre Enseñanza y Divulgación de las Ciencias*, *2*(2), 241–250.

Simonneaux, L. (2000). A study of pupils' conceptions and reasoning in connection with "microbes", as a contribution to research in biotechnology education. *International Journal of Science Education*, *22*(6), 619–644.

Songer, J., & Mintzes, J. (1994). Understanding cellular respiration: An analysis of conceptual change in college biology. *Journal of Research in Science Teaching*, *31*(6), 621–637.

Symington, V. (2010). Marvellous microbes. Society for General Microbiology.

Thiel, T. (1999). Bubbly Yeast. Science in the Real World: Microbes in Action. Retrieved from http://www.umsl.edu/~microbes/pdf/fungus1.pdf

Whittaker, H. (1969). New Concepts of Kingdoms of Organisms. *Science*, *163*(3863), 150–160.

Woese, R., Kandler, O., & Wheelis, L. (1990). Towards a natural system of organisms: proposal for the domains Archaea, Bacteria, and Eucarya. *Proceedings of the National Academy of Sciences of the United States of America*, *87*(12), 4576–4579.

CONSTRUCTION BY TEACHERS IN TRAINING OF A MODEL ANIMAL -ADAPTATION/ENERGY NEEDS-

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Abstract. Shown herein are the results of a training proposal concerning the scientific-pedagogic study of a model animal. The proposal is intended for the initial training of primary school teachers and it was carried out by 22 small groups formed of 3-4 future teachers. The results shown reflect their scientific knowledge. During the collaborative activity, the participants had to: a) describe the characteristics of an imaginary animal which lives in an extreme environment; b) determine what the designed animal needs energy for and c) indicate the characteristics/habits which would allow the animal to conserve energy.

- The future teachers described the animal, justifying its adaptive characteristics. They focused on morphological aspects and on behaviour. Other justifications were related to physiological aspects such as: a reduced need for food/water, the production of certain substances or the maintenance of body temperature.
- The students related energy needs with movement and vital functions. Fewer recognised the energy needs required for regenerating bodily structures or maintaining body temperature.
- The students focused on energy conservation in terms of thermal energy, associating it with the possession of morphological characteristics. The saving of other types of energy was considered less.

We can report that the activity was rated very positively with regard to its motivational nature and the possibilities of developing a model animal in connection with its adaptation and energy needs. Despite the fact that the ideas produced by the future teachers had some limitations, this is a first step towards addressing a profound didactic analysis.

Keywords: Models in science; Primary School; Teacher Thinking

INTRODUCTION

Creating models in the teaching of science is an aspect which has come to be recognised as important (Gilbert and Boulter 2000), along with the progression of learning within scientific modelling, seeing as it has important implications in curriculum design (Duncan and Hmelo-Silver 2009). Teaching must lead students to the gradual construction of explicatory models which are connected to the phenomena they explain (Acher et al. 2007; Schwarz et al. 2009). The concept of a living being is unifying in the teaching of the sciences (Caravita and Falchetti 2005). However, the school-taught model of a living being has not always been clearly defined and even biologists have not worried about the identification of this concept, given that they consider it to be too philosophical. In any case, in school science classes starting from primary education, the new approach is that an increasingly complex model of living beings in general and animals in particular must be constructed, taking into consideration the interaction between said organisms and their environment and also their adaptive characteristics (Gomez-Galindo et al. 2007).More specifically, it is important for school science to deal with the following key ideas: 1) living beings need to obtain matter/energy from the environment in order to stay alive and to do so they have mechanisms that allow them to ‘find out’ what goes on around them; 2) living beings change continuously (they ‘reconstruct’ themselves) and they modify the environment in which they live; 3) living beings perpetuate themselves, they produce copies which are similar to themselves and which

survive, as long as their characteristics are suited to staying alive in a changing environment (Pujol 2003; Garrido and Martínez-Losada 2009).
Furthermore, from the perspective of autopoiesis (Maturana and Varela 1981), a living being is perceived as a system which maintains itself thanks to the incorporation of energy from the environment. This is coherent with the importance given to energy as another unifying concept in the teaching of the sciences. Therefore, energy models must also be developed at the same time. This must stem from the notion that energy is 'something' required for things to function, leading to the idea of energy as the ability of systems to produce changes (Millar, 2005).

When teaching about energy, analysis must centre on phenomena which concern the physical world and the living beings in which the manifestations thereof can be observed. Specifically, different types of energy (kinetic, thermal, electric, etc.) must be detected and classified in such a way that is accessible to primary school students (García Carmona and Criado, 2013). It should be stressed that energy is transferred and transformed, and emphasis should be put on the fact that some of the energy is degraded in the transformations. The amount of energy that is conserved in these transformations and transfers should be taken into consideration. Based on the level of difficulty and abstraction in the aforementioned aspects, various authors (Liu and Mckeough, 2005; Newman et al., 2013; Martínez-Losada and Rivadulla, 2015) have created progression proposals which, in general terms, correspond to the following sequence:

a) Use as a starting point the perception of energy as an activity or ability to do things – energy is required for objects to function, for living beings to carry out our functions, etc.
b) Identify different types of energy
c) Note that energy is transferred and transformed
d) Recognise that a certain amount of energy is conserved

It is also appropriate to indicate that the study of energy is complicated even for students who have completed secondary education, seeing as it is an abstract concept. In particular, with regard to the energy in living beings, it has been ascertained that students do not know the sources of energy used by said beings (Boyes and Stanisstreet, 1991). They also seem to have difficulty in establishing the proper relationships between two key biological processes – photosynthesis and respiration – in the obtainment of energy (Brown and Schwartz, 2009).

The development of these models in primary school classrooms depends directly on teacher training. This in turn is dependent on teachers having sufficient scientific and pedagogic knowledge (Abell, 2007; Porlán et al., 2010) and this means that it is necessary to develop innovative, justified and evaluable training proposals. In this respect, an important aspect of teaching training is to make future teachers focus on school activities. This not only allows said teachers to detect their possible scientific limitations but it also allows them to analyse the learning possibilities of said activities and to identify their pedagogical value.

The aim is to analyse the results of a training proposal carried out with primary school teachers in training and focused on the study of a model animal – its adaptation and energy needs. Although the proposal is broader and addresses both scientific and pedagogic knowledge, we focus here on the science, giving responses to the following questions:

- When the future teachers design an imaginary animal which lives in an extreme zone, are they capable of justifying its adaptive characteristics?
- Which energy needs do they think that the designed animal must have?
- What characteristics do they give to the animal so that it can conserve energy? What type of energy is conserved?

METHOD

22 groups composed of 3-4 primary school teachers in training participated. In the training proposal they had to carry out an activity which was aimed at primary school students and inspired by one designed by Gil Quilez et al. (2008). The activity required them to: a) design an imaginary animal which is adapted for survival in a desert; b) determine what said animal needs energy for and c) indicate which characteristics/habits allow it to conserve energy.

The responses given by the groups of student teachers to each of the three questions, both in writing and taken from transcribed recordings, were analysed by grouping similar answers into categories and sub-categories. The categories established for each question are shown in Tables 1, 2 and 3.

RESULTS

The groups of students described the animal with references to: a) general aspects (size – large/small, classification – reptile, insect, etc.); b) functions (senses, feeding, reproduction, etc.); c) morphology (skin, limbs, etc.) and d) behaviour (see Table 1). The students justified its adaptations most in its morphology and behavioural aspects. However, they justified characteristics corresponding to functions far less, with the exception of functions which we would call other physiological aspects. The 18 groups which indicated these last characteristics justified the adaptation by referring to the maintenance of body temperature, a reduced need for water or the production of foul-smelling or poisonous substances for various ends.

Table 1. Characteristics of the imaginary animal pointed out by the student groups and/or justified in terms of their adaptation to the environment.

CATEGORIES		**No. of groups that quote**		
		No citing the adaptation	**No justifying the adaptation**	**Textual examples of the justifications**
General aspects	**Size**	9	13	"*It is small: It needs little food to obtain the nutrients it needs in order to obtain energy”* (A1)
	Classification	9	13	*“Imagine that the reptile has cold blood…that is convenient because, this way, it makes it through the day…"* (A19)
Morphology	**Skin**	1	19	*"Tan brown, similar to sand, so it can camouflage itself"* (A2)
	Limbs	3	18	*"It has a lot of small legs so it can move fast and avoid being buried in the sand* (A1)
	Other structures	-	21	"*Long tongue that allows it to hunt and get food"* (A2)

Functions	**Senses**	4	11	*"It has antenna. They are useful to orient itself and amplify sounds. This way, it will reach its destination earlier"* (A12)
	Diet	12	10	*"Omnivore. It can eat any food it finds, this is convenient because in the desert there is little food "* (A20)
	Reproduction	14	4	*"So, it shall lay a lot of eggs so at least one could survive [...]. Buried in the sand."* (A3)
	Other physiological aspects	-	18	*"Regarding the body temperature, it adapts to the desert climate, with very hot days and very cold nights" (*A24), *"They withstand thirst"* (A22) or *"... produce a characteristic body odour that attracts its prey " (*A6)
Behaviour		4	18	*"It sleeps during the hottest hours"* (A26)

The students recognised that the designed animals need energy to carry out five kinds of activities/actions (Table 2). Movement and vital functions were the most cited, while regulation of body temperature was the least indicated. Five groups indicated a need for energy in the storage of water, food and even energy.

Table 2. Designed animals' activities that need energy, according to the students.

Activities	Nº of groups	Textual examples
Movement	22 100%	*"To glide" (A30)*
Vital functions	20 90.9%	*"Perform the vital functions; let's say, nutrition and relation" (A25)*
Regeneration of structures	13 59.1%	*"To construct structures… restore its body" (A4)*
Regulation of temperature	8 36.4%	*"To maintain its body temperature" (A18)*
Storage	5 22.7%	*"...it also needs energy to store water during pregnancy…" (A24)* *"it stores energy in its tail so it can hunt during the night, making use of its illuminated tail"(A28)*

All groups recognised that their animal would need energy to carry out at least two types of activities/actions. The majority identified three and one group identified all five types (Figure 1).

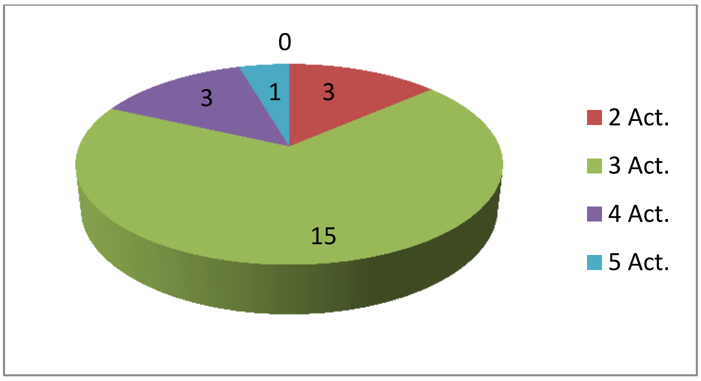

Figure 1. The number of groups which cited one, two, three, four or five different types of activities/actions which would require the use of energy.

All groups except one, which did not answer the question, indicated that their animal conserves some sort of energy. Furthermore, they associated this conservation with one or more characteristics related to its morphology, functions or behaviour (Table 3). The majority of the groups (sixteen in total) cited the conservation of heat energy, mainly associating it with the possession of morphological structures – *"The shell maintains the appropriate thermal energy. It keeps the heat from the day for the night and vice versa"* (A15). Five of these sixteen groups only noted this conservation in a generic way and they made errors: they believed that the maintenance of body temperature supposes a conservation of energy - *"it conserves energy because it regulates its body temperature..."* (A3). Thirteen groups indicated energy conservation associated with movement, connecting it above all with behaviour - *"When it is hunting, it camouflages itself and sits still to wait for its prey. It conserves energy"* (A6). The conservation of chemical energy, corresponding to the saving of food, was the least mentioned. The groups related it slightly more with functional characteristics – *"It has many young and the gestation period is very short, therefore saving energy"* (A4); than with morphological characteristics - *"it has a fat reserve system, so that it can store fatty materials from which it obtains energy"* (A4); or behaviour *"It stores food. When it is injured or in its reproductive phase it does not need to go outside to eat"* (A11).

Table 3. Energy savings suggested by student groups. Types of energy they refer to and animal characteristics they relate to them.

Type of energy	**Animal characteristics**			**Committed error**
	Morphology	**Functions**	**Behaviour**	
Related to movement Nº of groups =13	6	3	8	1
Calorific Nº of groups =16	10	4	4	5
Chemical (diet) Nº of groups =8	3	5	3	-

Note. The student groups were allowed to suggest more than one animal characteristic regarding the saving of the same type of energy.

CONCLUSIONS AND DISCUSSION

- The future teachers described the animal, justifying its adaptive characteristics. They focused on morphological aspects and on behaviour. Other justifications were related to physiological aspects such as: a reduced need for food/water, the production of certain substances or the maintenance of body temperature.
- The students related energy needs with movement and vital functions. Fewer recognised the energy needs required for regenerating bodily structures or maintaining body temperature.
- The students focused on energy conservation in terms of thermal energy, associating it with the possession of morphological characteristics. The saving of other types of energy was considered less.

We can report that the activity was rated very positively with regard to its motivational nature and the possibilities of developing a model animal in connection with its adaptation and energy needs. Despite the fact that the ideas produced by the future teachers had some limitations, this is a first step towards addressing a profound didactic analysis.

Focusing on the limitations shown by the groups of students, we can affirm that they had no problems in justifying the most evident adaptations of the animal they designed (the ones based on morphology or behaviour). However, they had more problems when justifying adaptations such as the type of diet or the reproduction of the animal, given that they did not identify, or perhaps did not know, the advantages of the aspects chosen for the good development of an individual in its environment.

Additionally, the students recognised the energy needs of the designed animal and referred above all and generically to the movement and functions of the body. This supposes, in addition to a lack of succinctness, a fairly reduced/simplistic view of energy: i.e. limited to kinetic energy (Liu & Mckeough, 2005; Newman et al., 2013; Martínez-Losada & Rivadulla, 2015). The references to other types of energy, such as thermal, were fewer in number and in many cases, errors were noted. In this regard, some groups stated that the ability to maintain body temperature would suppose a saving of energy, thus showing their lack of knowledge of the individual-environment transfer of heat.

Furthermore, with regard to energy saving, it is worth indicating that the teachers in training also related it to movement, specifically to the reduction/limitation of said movement. There were relatively few groups who referred to the saving or better use of food/nutrients which is associated with the saving or optimisation of chemical energy. This constitutes an important limitation, seeing as the consideration of this type of energy in relation to nutrition, in this case in animals, is very important for the construction of an appropriate school model of a living being (Pujol 2003; Garrido and Martínez-Losada 2009).

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REFERENCES

Abell, S. K. (2007). Research on Science Teacher knowledge. In S. K. Abell & N. G. Lederman (Eds.), *Handbook of Research on Science Education*. N.J: Lawrence Erlbaum Associates.

Acher, A., Arca, M., & Sanmartí, N. (2007). Modelling as a teaching learning process for understanding materials: A case study in primary education. *Science Education, 91*(3), 398-418.

Boyes, E., & Stanisstreet, M. (1991). Misconceptions in first-year undergraduate science students about energy sources for living organisms. *Journal of Biological Education, 25*(3), 209-213.

Brown, M. H., & Schwartz, R. S. (2009). Connecting Photosynthesis and Cellular Respiration: Pre-service Teachers' Conceptions. *Journal of Research in Science Teaching, 46*(7), 791-812.

Caravita, S., & Falchetti, E. (2005). Are bones alive? *Journal of Biological Education, 39*(4), 163-170.

Duncan, R. G., & C. E. Hmelo-Silver. 2009. "Learning Progressions: Aligning Curriculum, Instruction and Assessment." Journal of Research in Science Teaching 46 (6): 606–609.

García-Carmona, A. & Criado, A. (2013) Enseñanza de la energía en la etapa 6-12 años: un planteamiento desde el ámbito curricular de las máquinas. Enseñanza de las ciencias 31(3), 87-102.

Garrido, M., & Martínez-Losada, C. 2009. ¿Qué Enseñar Sobre los Seres Vivos en los Niveles Educativos Iniciales? Aula 183–184: 34–36.

Gil Quilez, M. J., De la Gándara, M., Dies, M. E., & Martínez Peña, B. (2011). Animales extraordinarios: la construcción y uso de modelos en la Escuela Primaria. *Investigación en la Escuela, 74*, 89-100.

Gilbert, J. K., & Boulter, C. (2012). *Developing models in science education*: Springer Science & Business Media.

Gómez Galindo, A., Sanmartí, N., & Pujol, J. (2007). Fundamentación teórica y diseño de una unidad didáctica para la enseñanza del modelo ser vivo en la escuela Primaria. *Enseñanza de las Ciencias, 25*(3), 325-340.

Liu, X, & McKeough A. (2005). Developmental Growth in Students' Concept of Energy: Analysis of Selected Items from the TIMSS Database. J*ournal of Research in Science Teaching* 42: 493-517.

Martínez-Losada, C. & Rivadulla López, J.C. (2015). ¿Cómo progresar en la enseñanza de la energía? Alambique 79,17-24.

Maturana, H., & Varela, F. J. (1981). *Autopoiesis and Cognition: The Realization of the Living.* (Vol. 42). Boston: Dordrecht: D. Reidel.

Millar, R. (2005). *Teaching about energy* (pg. 1-21). York, UK: University of York, Department of Educational Studies.

Neumann, K., Viering, T., Boone, W.J. & Fischer, H.E. (2013): "Towards a learning progression of energy". *Journal of Research in Science Teaching, 50*(2), pg. 162-188.

Porlán, R., Martín del Pozo, R., Rivero, A., Harres, J., P., A., & Pizzato, M. (2010). El cambio del profesorado de ciencias I: Marco teórico y formativo. *Enseñanza de las Ciencias, 28*(1), 31-46.

Pujol RM. *Didáctica de las Ciencias en la Educación Primaria*. Madrid: Síntesis, 2003.

Schwarz, C. V., Reiser, B. J., Davis, E. A., Kenyon, L., Achér, A., Fortus, D., Shwartz, Y., Hug, B. & Krajcik, J. (2009). Developing a Learning Progression for Scientific Modeling: Making Scientific Modeling Accessible and Meaningful for Learners. *Journal of Research in Science Teaching 46*(6), 632–654.

HOW THE SCIENTIFIC AND PEDAGOGICAL APPROACHES TO ENERGY TEACHERS IN TRAINING EVOLVE

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Abstract: The purpose of this paper is to know how much the energy-related ideas and approaches of future school masters evolve and which aspects dealing with energy need to be tackled in Primary Education (6-12 years), both before and after they are given their subject-specific training. This study was carried out at the University of A Coruña (Spain) among 231 second-year Primary School Degree and 147 third-year undergraduates. Data were collected a) during Year 2, before undertaking the scientific/pedagogical analysis of the subject of energy and b) at the beginning of Year 3, within a framework where students are asked to reflect on what they learned during the previous Academic Year. The instrument employed was a questionnaire with two open questions: a) What is energy for you, what does the term suggest?; b) Which energy-related aspects should be treated during Primary Education?

The participants initially have a limited idea about what energy is, focusing mainly on the different types and its usefulness. They also consider that energy consumption related aspects are what should be dealt with in Primary Education, although they place little stress on the environmental impact resulting from it. After receiving subject-specific education, the participants´ scientific ideas and approaches improve in terms of what type of concept of energy should be conveyed in Primary Education. However, no improvements are detected concerning their opinions on how to tackle teaching energy use related aspects, nor regarding the associated environmental issues.

All of this shows that even though the education proposal has promoted advances in terms of scientific and pedagogical knowledge of future school masters, their training needs to emphasize how to determine a scientifically accurate idea of what energy is and how to apply it to relevant personal and social contexts, which must likewise be comprehensible for Primary School children.

Keywords: primary education, energy, teacher training

INTRODUCTION

Energy is an important topic in Science Education because it is essential for us to understand and grasp the physical, biological and technological world surrounding us. Not only does studying it allow us to explain how and why different phenomena occur, but it also allows us to understand the role played by energy in our society (Driver & Millar, 1986). Treating the scientific and social dimension of energy is therefore recommended, including the way people use it and the socio-environmental problems linked to the way it is obtained and consumed (García, Rodríguez, Solís & Ballenilla, 2007; Domenech, Gil-Pérez, Gras-Martí, Guisasola, Martínez-Torregrosa, Salinas, …Vilches, 2007).

Even though some authors believe that the concept of energy should be introduced in schools once pupils are able to use abstract thinking and reasoning, there are others who have defended that it would be convenient to begin to study this topic even at the initial stages of schooling (Solomon, 1983; Trumper, 1993). At basic educational levels, the topic of energy should logically be treated in a close and familiar context and suitable progress modules be established (Liu & McKeough, 2005; Neumann, Viering, Boone & Fischer, 2013). Thus, moving forward from an idea of energy as “something” needed to make things work to another, associated with systems having the capacity to bring about changes, is recommended (Millar, 2005; García-Carmona & Criado, 2013). Identifying where and when the amount of energy increases and decreases in specific situations, facilitates making progress in terms of identifying its characteristics – it occurs in many different ways, it can be transformed or transferred from one system to others, it dissipates or is devaluated in the transformation/transfer processes; energy is thus never available to be used again, although it is preserved globally (Harlen, 2010). This last aspect will help to understand, in its turn, why it is of the essence to use available energy resources in a rational way as well as comprehending how the energy we consume is obtained, and the impact such processes has on the individual and society alike (Martínez-Losada & Rivadulla, 2015).

However, conceptualizing it is no easy task given the high degree of abstraction involved. In this sense, several inaccurate conceptions have been detected among children and teenagers. More specifically, pupils tend to associate energy with strength and physical exercise, consider it to be a sort of fuel which can be obtained and lost, and limit the existence of energy to things in motion and so forth (Solomon, 1982; Driver, Squires, Rushworth & Wood-Robinson, 1994).

Education does not appear to promote the much needed evolution of pupil´s conceptions of energy, since inaccurate ideas have also been found amongst working (Kruger, Palacios & Summers, 1992) and training Primary School teachers (Trumper, 1997; Trumper, Raviolo & Shnersch, 2000). It is also noteworthy that studies carried out in Spain have shown that teachers in training find recognizing the existence of energy hard when it is not present in a manifest way, as is the case with internal energy or chemical energy (Rodríguez Marín & Garcia, 2011). Moreover, difficulties have been detected when applying the idea of energy transfer to analysing well-known and familiar situations, displaying how tough it can be to take in and apply the idea of energy preservation to such situations. (Ibañez & Barrau, 2014).

On the other hand, energy is taught in a deficient manner. So it is that, despite the unifying nature of the concept of energy, studying it is normally introduced within the framework of mechanics, thereby associating it with the concept of work and limiting the preservation principle to situations where kinetic and potential energy are transformed. At a later stage, other sorts of enery (thermal, electrical and so forth) are dealt with within the framework of Physics in a compartimentalized way (Koliopoulos & Ravanis, 1998). Furthermore, and in spite of the concept of energy being applied to other branches of Science, different meanings are given to it in each one of those branches. (Bächtold & Guedj, 2014).

Yet another issue when teaching about energy is that it tends to prioritize scientific concepts to analysing different phenomena. This has been clearly noticed whilst studying the Training Framework for Primary School teachers. (Martín, Prieto & Jiménez, 2013).

Improving energy teaching, just like that of any other subject, means that school masters are required to have sufficient scientific and pedagogical competences, which they need to develop during their training stage at Teaching College (Abell, 2007; Porlán, Martín del Pozo, Rivero, Harres & Pizato, 2010). It is, amongst other factors, a matter of school masters developing what Shulman (1986) called pedagogical content knowledge (PCK), which integrates scientific, pedagocical and contextual knowledge.

In the framework of teacher training, and more specifically in the sphere of energy teaching Bächtold & Guedj (2014) propose articulating the contents around the following topics, based on Epistemology and the History of Science and Technology: What is the origin of the concept of energy?, What is energy?, What purpose does the concept of energy serve?.

Other researchers (e.g., such as Nordine, Krajcik and Fortus, 2011) justify the need for education to stress and highlight the ideas of energy transformation and transfer to interpret and explain everyday phenomena. At the same time, there is a need to introduce the analysis of relevant socio-scientific issues connected with the aforementioned situations, such as the environmental impact of energy use, whose educational value is not always sufficiently recognized by Teachers in Training (Campbell & Lubben, 2000; Martín, Prieto & Jiménez, 2013). In keeping with this line of thought, other cores to be studied as well as situations to be analysed for Primary School Teacher Training have been defined – energy in situations physically close to us, in living beings…, with a connection to human societies as their common denominator- (García-Barros, Martínez-Losada, González & Bugallo, 2012).

The purpose of this paper is, more specifically, to learn how much the energy-related ideas and approaches of future school masters evolve and which aspects dealing with energy need to be tackled in Primary Education (6-12 years), both before and after they are given their subject-specific training.

METHOD

The study was undertaken with Primary School Teacher undergraduates at A Coruña University (Spain).

Data were collected at two different times: a) in Year 2 of the Degree, before undertaking the scientific/pedagogical analysis of the subject of energy; b) at the beginning of Year 3 of the Course, within a framework where students are asked to reflect on what they learned during the previous Academic Year. In Year 2 231 took part, of which 147 voluntarily agreed to continue participating in the study during Year 3.

More specifically, in Year 2, the training proposal endeavors to enable students to (García-Barros, Martínez-Losada, González & Bugallo, 2012).:

- Acquire an accurate idea of what energy, going beyond limited conceptions of it;
- Identify a desirable model of how to deal with energy in Primary School, taking into account how relevant it is from a personal and social point of view as well as how difficult it is for children to grasp and learn it;
- Apply the aforementioned model to the analysis of everyday situations (objects and materials which move, undergo temperature changes, are burnt…; different devices and machines operating; etc);
- Analyzing and designing specific activity sequences aimed at this educational stage, catering to the scientific and social dimensions of energy.

The instrument employed to gather the data was a questionnaire made up of two open questions: a) What is energy for you, what does the term suggest?; b) Which energy-related aspects should be treated during Primary Education?

The answers collected are grouped into three different categories: a) a definition of energy, b) the qualities of energy y c) how energy is used in our society. For each one of these, corresponding subcategories were established and representative examples given by the students are shown, as seen in Table 1.

Table 1. Categories and subcategories established and representative examples answers collected

Answer categories		Representative examples
Definition	Capacity of systems to bring about changes	*“Es una propiedad que tienen todos los cuerpos, permite realizar cambios en los materiales”*
	Associated with power and/or motion	*“Característica que tiene un cuerpo al ejercer una fuerza sobre él” “Se hace presente en el movimiento”*
	That which makes things work	*“Hace funcionar algo…, coches, personas…”*
Qualities	Types/Forms	*“Hay muchos tipos de energía, como eléctrica…” “existen distintas formas de energía”*
	Preservation	*“No se crea y tampoco se destruye… no desaparece”*
	Transformation/ Transference	*“Se transforma, por ejemplo de energía eléctrica a energía cinética” “Se puede transmitir”*
Uses	Usefulness/importance	*“Puede tener múltiples finalidades” “Sin energía no podríamos vivir”*
	Origin/Production	*“Hay diferentes formas de obtenerla del medio””Existen distintas fuentes de energía…”*“
	Environmental impact	*… repercute en el medio… hay que usarlas correctamente y sin abusar…”*

RESULTS

Before receiving their specific training (see Figure 1),

- 56.7% of the participants give a definition of energy, 54.1% speak about its qualities and a slightly higher percentage makes reference to its use.
- The great majority of teachers in training consider that this last aspect should be dealt with in Primary Education. Moreover, 58.9% of the subjects mention the qualities of energy whereas only 38.5% make reference to its definition.

After receiving their specific training (see Figure 1),

- The percentage of subjects who refer to the qualities of energy and make reference to its definition is larger than initially (66.0% and 68.7% respectively). However, only 22.4% mention its use.
- As for the aspects to be treated in Primary School, the subjects make more reference to the qualities (77.6%) than to use of energy (58.5%) and its definition (46.3%). However, while the percentage of subjects referring to the qualities of energy and its definition is larger than it was initially, the subjects referring to its use are fewer.

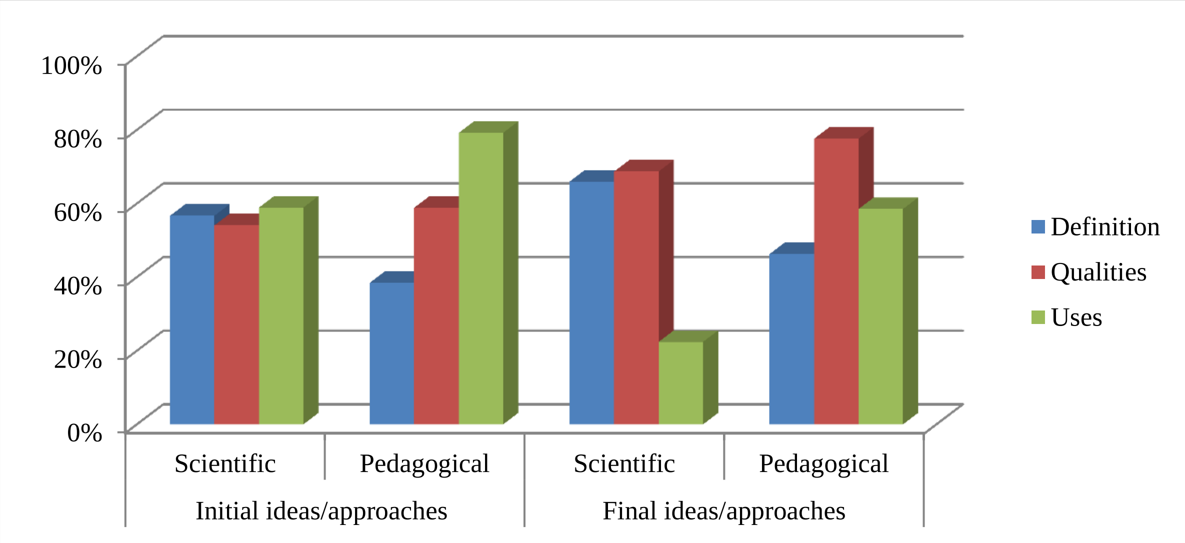

Figure 1. Percentage of participants who contribute different scientific and pedagogical ideas and approaches before and after receiving education on this particular **topic.**

We subsequently present the most detailed analysis of the contributions made by the participants (Table 2).

The subjects initially talk about the importance of a definition of energy associated with power and motion, although the percentage considering that such a definition should be dealt with in Primary Education is smaller. Only 6.9% of the subjects conceptualize energy as the capacity of systems to bring about changes and 5.2% considering that such a definition should be dealt with in Primary Education.

As regards the qualities of energy, the participants consider that mainly the various types of it ought to be treated in Primary School (40.7% and 55.4%, respectively). Only a small percentage of the subjects mention theidea of energy transformation/transmission and consider that it should be dealt with (5,6% and 6,5%).

As far as its uses are concerned, the subjects refer to its origin/production (44.6%) as well as its usefulness/importance (30.7%) and more than 50% consider that both aspects are suitable for Primary Education. Only 1.3% of the participants activate environmental impact related ideas and approaches associated with energy consumption, though 21.2% admit that this issue should actually be tackled in Primary School.

Afterwards, the vast majority of the participants mentioning a definition of energy conceptualize it as the capacity to bring about changes (49.7% del total), whilst also believing that such a definition is suitable for Primary Education (34.7%).

On the other hand, even though the subjects mention varying qualities (types, preservation, and transformation/transference) they feel that it is chiefly the different types of energy which should be dealt with in Primary School (61.2%).

As for its uses, the participants mention and also consider that its usefulness/importance and its origin/production should be tackled in Primary School. The percentage of subjects referring to the environmental impact associated with energy consumption is similar to the one detected initially.

Table 2. Types of scientific and pedagogical ideas and approaches mentioned by teachers in training, before and after getting subject-specific education

Answer categories		Initial ideas/approaches (n=231)		Final ideas/approaches (n=147)	
		Scientific	Pedagogical	Scientific	Pedagogical
Definition	Capacity of systems to bring about changes	16 6.9%	12 5.2%	73 49.7%	51 34.7%
	Associated with power and/or motion	75 32,5%	42 18,2%	9 6,1%	10 6,8%
	That which makes things work	40 17,3%	35 15,2%	15 10,2%	7 4,8%
Qualities	Types/Forms	94 40,7%	128 55,4%	52 35,4%	90 61,2%
	Preservation	41 17,7%	15 6,5%	56 38,1%	26 17,7%
	Transformation/ Transference	13 5.6%	15 6.5%	38 25.9%	48 32.7%
Uses	Usefulness/importance	71 30,7%	138 59,7%	25 17,0%	62 42,2%
	Origin/Production	103 44,6%	124 53,7%	13 8,8%	33 22,4%
	Environmental impact	3 1,3%	49 21,2%	5 3,4%	31 21.1%
No Answer		-	2 1,4%	-	2 1,4%

DISCUSSION AND CONCLUSIONS

The participants initially have a narrow idea of what energy is. It is associated with power and motion and, therefore, to the field of mechanics, which is in keeping with the results obtained during research undertaken in this field with training Primary School teachers (Trumper, 1997; Trumper *et al*, 2000).

The participants' ideas are likewise highly focused on the types of energy, perhaps owing to the stress which instruction has traditionally given to identifying and characterizing (Koliopoulos & Ravanis, 1998), it, as well as on how it is used and obtained from different energy sources. In line herewith, he future school masters also consider that, especially, this particular quality should be treated in Primary School and particularly energy consumption related aspects. However, they barely stress its environmental impact despite being a highly relevant topic for debate in society and needs to be transferred to schools (Campbell & Lubben, 2000; Domenech *et al*, 2007; Rodríguez Marín & Garcia, 2011).

The participants' scientific ideas and approaches improve after getting educated in that they contribute a more accurate definition of what energy is, i.e., associated with a capacity of systems to bring about changes (Millar, 2005; García-Carmona & Criado, 2013). In addition to this, they recognize a greater number of energy-related qualities, and they more specifically recognize energy transfer/transformation and preservation. Such improvements may be seen, too, in their opinions about what type of concept of energy should be conveyed to Primary School teaching. The aforementioned leads us to believe that the Training Proposal, which is based on analyzing everyday situations and designing sequences of specific activities aimed at

Primary Education, has promoted advances in terms of scientific and pedagogical knowledge of future school masters. The greater degree of attention given to energy transformation is relevant, in that it, facilitates identifying changes occurring in different systems, which, no doubt, helps to develop an accurate conceptualization of what energy is (Harlen, 2010; Nordine, Krajcik and Fortus, 2011).

After getting educated, the participants do not make such a lot of reference to the pedagogical importance of the different uses of energy. In fact, no references at all are seen in terms of the environmental impact of energy. This may be due to the fact that the degree course training activities did not stress these aspects well enough. It is likewise possible that the teachers in training may have focused their attention and effort on the scientific knowledge about energy acquired throughout their education, thereby leaving other aspect aside. However, such knowledge is particularly important and relevant from a personal and social point of view.

Be that as it may, our training proposal does need improving, at any rate. In line with this, stress should be placed on identifying and analyzing socio-scientific issues, contextualized by means of their most well-known everyday expressions, from a scientific and educational point of view in order to favor the development of the previously mentioned scientific school model, as well as developing responsible energy consumption related attitudes and behavior (Campbell & Lubben, 2000; Domenech *et al*, 2007; Martín, Prieto & Jiménez, 2013).

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REFERENCES

Abell, S. K. (2007). Research on science teacher knowledge. En S. K. Abell & N. G. Lederman (Eds.), *Handbook of Research on Science Education* (pp. 1105-1149). New Jersey: Lawrence Erlbaum Associates.

Bächtold, M. & Guedj, M. (2014). Teaching energy informed by the history and epistemology of the concept with implications for teacher education. In M.R. Matthews (Ed.), *Intenational Handbook of Research in History, Philosophy and Science Teaching* (pp. 211-242) New York: Springer

Campbell, B. & Lubben , F. (2000). Learning science through contexts: helping pupils make sense of everyday situation. *International Journal of Science Education, 22*(3), 239-252.

Domenech, J. L., Gil-Pérez, D., Gras-Martí, A., Guisasola, J., Martínez-Torregrosa, J., Salinas, J., Trumper, R., Valdes, P. & Vilches, A. (2007): Teaching of energy issues: A debate proposal for a global reorientation. *Science & Education, 16*(1), 43-64.

Driver, R. & Millar, R. (Eds.) (1986): *Energy matters*. Leeds: University of Leeds.

Driver, R., Squires, A., Rushworth, P. & Wood-Robinson, V. (1994) *Making Sense of Secondary Science: Research into children's ideas*. New York: Routledge.

García, J. E., Rodríguez, F., Solís, M. C. & Ballenilla, F. (2007). Investigando el problema del uso de la energía. *Investigación en la Escuela, 63*, 29-45

García-Barros, S., Martínez-Losada, C., González, C. & Bugallo, A. (2012). La energía en la formación de maestros. In: *XXV Encuentros de Didáctica de las Ciencias Experimentales*. Santiago de Compostela 5-7 september 2012.

García-Carmona, A. & Criado, A. (2013). Enseñanza de la energía en la etapa 6-12 años: un planteamiento desde el ámbito curricular de las Máquinas. *Enseñanza de las Ciencias, 31*(3), pp. 87-102

Harlen, W. (Ed.). (2010). *Principles and big ideas of science education*. Hatfield: Association for Science Education.

Ibáñez, M. & Barrau, J. (2014). El balance energético en escenarios reales. Propuesta didáctica en la formación inicial de maestros *Revista Eureka sobre Enseñanza y Divulgación de las Ciencias*, 11(2), 216-230.

Koliopoulos, D. & Ravanis, K. (1998). L´enseignement de l´énergie aun collége vu par les enseignants. Grille d´analyse de leurs conceptions. *Aster, 26*, 167-182

Kruger, C., Palacio, D. & Summers, M. (1992). Surveys of English primary school teachers' conceptions of force, energy and materials. *Science Education, 76,* 339–351.

Liu, X. & McKeough, A. (2005). Developmental growth in students´ concept of energy: Analysis of selected items from the TIMSS database. *Journal of Rechearch in Science Teaching, 42*(5), 493-517.

Martín, C., Prieto, T. & Jiménez, M. A. (2013). Algunas creencias del profesorado de ciencias en formación sobre la enseñanza de la problemática de la energía. *Revista Eureka sobre Enseñanza y Divulgación de las Ciencias, 10*, 649-663

Martínez-Losada, C. & Rivadulla, J. C. (2015). ¿Cómo progresar en la enseñanza de la energía? *Alambique, 79*, 17-24.

Millar, R. (2005). *Teaching about energy*. York: University of York

Neumann, K., Viering, T., Boone, W. J. & Fischer, H. E. (2013). Towards a learning progression of energy. *Journal of Research in Science Teaching, 50*(2), 162-188.

Nordine, J., Krajcik, J. & Fortus, D. (2011). Transforming Energy Instruction in Middle School to Support Integrated Understanding and Future Learning. *Science Education, 95*(4), pp. 670-699.

Porlán, R., Martín del Pozo, R., Rivero, A., Harres, J. P., A., & Pizzato, M. (2010). El cambio del profesorado de ciencias I: Marco teórico y formativo. *Enseñanza de las Ciencias, 28*(1), 31-46.

Rodríguez Marín, F. & García E. (2011). ¿Qué diferencias hay entre el conocimiento cotidiano y el conocimiento científico de docentes en formación sobre el concepto de energía? *Investigación en la Escuela*, 75, 63-71

Solomon, J. (1982). How children learn about energy, or Does the first law come first? School Science Review , 63 (224), 415-422

Solomon, J. (1983). Learning about energy; How pupils´ think in two domains. *European Journal of Science Education, 5*, 49-59

Shulman, L. (1986). Those who understand: knowledge growth in teaching. *Educational Researcher, 15*(2), 4-14.

Trumper, R. (1993). Children´s energy concepts. *International Journal of Science Education, 15*, 139-148

Trumper, R. (1997). The need for change in elementary school teacher training: the case of the energy concept as an example. *Educational Research, 39* (2), 157-174

Trumper, R., Raviolo, A. & Shnersch, A. M. (2000). A cross-cultural survey of conceptions of energy among elementary school teachers in training — empirical results from Israel and Argentina. *Teaching and Teacher Education*, *16* (7), 697-714

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PEDAGOGICAL AND SCIENTIFIC BELIEFS OF FUTURE PRIMARY SCHOOL TEACHERS AND UNIVERSITY SCIENCE EDUCATION AND SCIENCE LECTURERS

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Abstract: This study presents an analysis of the reflections of three university science lecturers (AXL, MYA and PAB) taking part in a training process at the University Corporation of Bogotá (Colombia), designated *Supervisión*. The basic aim of the supervision process, agreed beforehand with faculty, consisted of accompanying the lecturer (teacher) throughout an educational innovation consisting of designing argumentation activities in the context of their university teachings, to promote and achieve better quality participation from the students, designated argumentative participations. The intention was to steer the various faculty teaching models towards more interactive and student-focused models, designed to favour their knowledge building. After completing the supervision process, three final reflexive activities were requested, identified as *public presentation, self-reporting and individual interview*, which were the sources of the reflective codes in this study.

Keywords: pedagogical beliefs, image of science, teacher trainers

INTRODUCTION

The beliefs of future teachers embarking on their science education studies tend to be in line with the traditional teaching model, with the subsequent gradual incorporation of constructivist models, without the latter replacing the former (Martín del Pozo, Porlán & Rivero, 2011). Teachers' beliefs are psychological constructs widely acknowledged in Educational Professional Development. They are framed within the mediational paradigm of "teacher thinking", where the teacher's behaviour is guided by a private and implicit personal system of beliefs which act as non-rational mediators of their teaching planning. For science teachers, the important beliefs concern: i) Image of Science, ii) Learning of Science and iii) Science Teaching; the three categories that form the vertices of the didactic triangle. Table 1 synthesises the main ideas associated with the cited models.

Our aim in this work is twofold:

a) To examine the beliefs held by future primary school teachers (group 1; N = 60) at the onset of their science education course.

b) To compare said beliefs with those of university lecturers in science education (group 2; N = 33) and sciences (group 3; N = 98).

As a starting point, it is assumed that the beliefs of prospective teachers are closer to those of science lecturers than to lecturers in science education.

Table 1. Teaching models and main associated beliefs.

	Traditional Model	Constructivist Model
Nature of Science	Science absolute and true	Science is paradigmatic, i.e. contextualized and subject to prior knowledge, techniques and structures.
Learning of Science	Cognitive structure as an "empty box". Learning by listening and repeating.	Full cognitive structure. Learning by reconstruction, through physical, vicarious and symbolic interactions.
Science Teaching	Teacher explains and students perform activities	Students solve problems (from their daily life, socio-scientific…) through research methodology, whereby they perform, think about and regulate their own learning and work in interaction with their peers, discussing and sharing ideas.

METHOD

We reviewed several instruments: the Inventory of Educational and Scientific Beliefs, INPECIP (Porlán, 1989), the Professional and Pedagogical Experience Repertoire (Loughran, Mulhall & Berry, 2004) and others (Martínez et al., 2001; Marín & Benarroch, 2009; 2010; Benarroch & Marín, 2011). Finally, INPECIP was chosen for its brevity and its widespread application.

The questionnaire versions used (in Spanish) may be found at:

- http://goo.gl/forms/YAsWyJtwHB, for future teachers;
- http://goo.gl/forms/1RbBvlVDQ9, for university lecturers in science teaching; and
- http://goo.gl/forms/qxT7izBWNh, for university science lecturers.

INPECIP (Table 2) consists of 51 Likert-type statements with 5 response options (1 = strongly disagree; 5 = strongly agree).

Table 2. INPECIP questionnaire structure.

	Nº Statements	Statements
Nature of Science	14	55, 51, 47*, 44*, 42*, 40*, 39, 38, 28, 23, 22*, 21*, 11, 4*
Learning of Science	14	54, 50, 48*, 46*, 41*, 35*, 33, 32, 27*, 24*, 19*, 14, 8, 5
Science Teaching	23	56, 52, 49, 45, 43*, 37*, 36*, 34*, 31*, 30, 26, 25, 20*, 17*, 16, 15, 13, 10, 9*, 7*, 6*, 2*, 1
Total	51	

*items corresponding to the traditional model

The survey was carried out in March 2014 with future teachers who were taking a course at the University of Granada to further their studies from 180 to 240 credits. Teacher collaboration, extended to the whole of Spain, was achieved by means of an anonymous questionnaire, inviting them to take part in the research by e-mail in the first semester of academic year 2014-2015.

We analysed the answers provided by a total of 60 students on a Degree course in Primary Education, 33 Science Education lecturers, without any experience in the INPECIP test, and 98 university Science lecturers. Table 3 synthesises some features of the samples.

Table 3. Sample characteristics.

<table>
<tr><th colspan="2">Sample</th><th>N</th><th>Characteristics</th></tr>
<tr><td>Group 1</td><td>Primary School Teachers in Training</td><td>60</td><td>66% are female and 33% are male.
15% had studied “Science Education” during their previous degree course.
70% had no teaching experience.
23% had less than 5 years of teaching experience.
5% had between 5-10 years of teaching experience.
2% had more than 20 years of teaching experience.</td></tr>
<tr><td>Group 2</td><td>University Lecturers in Science Education</td><td>33</td><td>66% are female and 33% are male.
58% had never heard of the INPECIP test.
42% knew about its existence, but had not worked with it.</td></tr>
<tr><td>Group 3</td><td>University Lecturers in Science</td><td>98</td><td>32% are female and 68% are male.
Include almost all the main knowledge areas:
<table>
<tr><th>Area</th><th>Number of participants</th><th>Percentage</th></tr>
<tr><td>Geology</td><td>40</td><td>40.8%</td></tr>
<tr><td>Chemistry</td><td>19</td><td>19.4%</td></tr>
<tr><td>Physics</td><td>14</td><td>14.3%</td></tr>
<tr><td>Pharmacy</td><td>11</td><td>11.2%</td></tr>
<tr><td>Biology</td><td>3</td><td>3.1%</td></tr>
<tr><td>Engineering</td><td>3</td><td>3.1%</td></tr>
<tr><td>Others</td><td>8</td><td>8.2%</td></tr>
</table>
55% had less than 18 years of teaching experience.
43% had between 18-24 years of teaching experience.
2% had more than 24 years of teaching experience.</td></tr>
</table>

RESULTS

First of all, we calculated the basic statistical parameters of each item in every category. We transformed the results corresponding to the variables associated with the less constructivist sentences, as follows: “1” is transformed into “5”, “2” is transformed into “4”, “3” remains unchanged, and so on. After this transformation, a high score indicated, in all items, a more constructivist trend.

Our first objective is to calculate the global indexes that provide information on the thinking of the different groups of participants, for every category (Table 4).

As these variables are not normally distributed (confirmed using both Anderson-Darling and Kolmogorov-Smirnoff tests), we employed a non-parametric Mann-Whitney test (Table 5).

Table 4. Mean results by category and group.

		Mean	Estimated error of the mean	Standard deviation	Variance	Min.	Q1	Median	Q3	Max.
Image of Science	Group 1	3.07	0.03	0.24	0.06	2.50	2.93	3.00	3.21	3.57
	Group 2	3.83	0.10	0.60	0.36	2.86	3.32	3.71	4.25	5.00
	Group 3	3.05	0.03	0.27	0.08	2.07	2.86	3.00	3.21	3.86
Learning of Science	Group 1	3.52	0.05	0.36	0.13	2.86	3.24	3.43	3.71	4.42
	Group 2	4.02	0.09	0.54	0.29	3.00	3.61	4.14	4.43	4.79
	Group 3	3.27	0.04	0.38	0.14	2.50	3.00	3.21	3.50	4.57
Science Teaching	Group 1	3.09	0.02	0.18	0.03	2.52	3.00	3.09	3.22	3.52
	Group 2	3.48	0.07	0.40	0.16	2.74	3.22	3.48	3.76	4.43
	Group 3	2.94	0.02	0.23	0.05	2.48	2.82	2.91	3.09	3.52

In each category, Science Education lecturers are more “constructivist” than both their students and their colleagues from Science departments. In the “Learning of Science” and “Science Teaching” categories, students are shown to be somewhat more “constructivist” than university science lecturers, but less so than lecturers in science education.

Table 5. Study of significant differences between groups.

		Difference of means	Mann-Whitney test (p-value)	¿Are there significant differences?
Image of Science	Groups 1-2	-0.760	0.00	Yes
	Groups 2-3	0.781	0.00	Yes
	Groups 1-3	0.022	0.50	No
Learning of Science	Groups 1-2	-0.504	0.00	Yes
	Groups 2-3	0.753	0.00	Yes
	Groups 1-3	0.249	0.00	Yes
Science Teaching	Groups 1-2	-0.388	0.00	Yes
	Groups 2-3	0.540	0.00	Yes
	Groups 1-3	0.152	0.00	Yes

Results show statistically significant differences between all pairs of groups ($p<0.001$), except in the case of the “Image of Science” category of groups 1 and 3 ($p=0.5$).

DISCUSSION AND CONCLUSIONS

The results show some coherence between Image of Science, Learning of Science and Science Teaching among each population group. Thus, university lecturers in science teaching are shown to be the most constructivist in the three categories, with university science lecturers the least. The data obtained are consistent with those of other studies (Martín del Pozo, Porlán & Rivero, 2011) in terms of the tenuous alignment of the beliefs of future primary teachers with the constructivist models of science teaching. It does not seem paradoxical that prospective teachers' beliefs are closer to those of university science teachers than to those of science education lecturers, as the former will have been the main trainers of secondary teachers who, in turn, have taught science to pupils prior to their admission to university. Moreover, pupils will probably have had less contact with science education faculties, or none at all to date.

It is striking that, overall, members of the university faculty of sciences turn out to be more traditional, not only in terms of teaching and learning, but also in the Image of Science category (they themselves are creators of science), where a significant difference is found with science education lecturers, although not with students.

In any case, these ideas are far removed from the most advanced proposals on science and its teaching-learning, so channels must be found that facilitate communication and understanding among the different stakeholders responsible for the beliefs of future teachers. To quote Claessens (2007, p.2), "It is perhaps scientists who should be the first to speak out and show the way".

ACKNOWLEDGEMENTS

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REFERENCES

Benarroch, A. & Marín, N. (2011). Relaciones entre creencias sobre enseñanza, aprendizaje y conocimiento de ciencias. *Enseñanza de las Ciencias*, 29 (2), 289-304.

Claessens, M. (2007). El eslabón perdido. *Research*EU*, número especial, p.2.

Loughran, J., Mullhall, P., & Berry, A. (2004). In search of pedagogical content knowledge in science: Developing ways of articulating and documenting professional practice. *Journal of Research in Science Teaching*, 41 (4), 370–391.

Marín, N. & Benarroch, A. (2009). Desarrollo, validación y evaluación de un cuestionario de opciones múltiples para identificar y caracterizar las visiones sobre la naturaleza de la ciencia de profesores en formación. *Enseñanza de las Ciencias*, 27 (1), 89-108.

Marín, N. & Benarroch, A. (2010). Cuestionario de opciones múltiples para evaluar creencias sobre el aprendizaje de las ciencias. *Enseñanza de las Ciencias*, 28 (2), 245–260.

Martín del Pozo, R., Porlán, R., & Rivero, A. (2011). The progression of prospective teachers' conceptions of school science content. *Journal of Science Teacher Education*, 22 (4), 291-312.

Martínez, M.M., Martín del Pozo, R., Rodrigo, M., Varela, P., Fernández, P. & Guerrero, A. (2001). ¿Qué pensamiento profesional y curricular tienen los futuros profesores de ciencias de Secundaria? *Enseñanza de las Ciencias*, 19 (1), 67-87.

Porlán, R. (1989). Teoría del conocimiento, teoría de la enseñanza y desarrollo profesional. Las concepciones epistemológicas de los profesores. Tesis Doctoral inédita. Universidad de Sevilla.

EXPERIMENTAL MICROCOMPUTER-BASED ACTIVITIES DEVELOPED AND IMPLEMENTED BY PRE-SERVICE PRIMARY TEACHERS

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Abstract: In reviews on lab work it becomes apparent that the opportunities provided for an active engagement of students in experimentation and in becoming familiar with key methods of scientific inquiry are still rather limited. Inadequate professional development has frequently been mentioned as a reason for not carrying out such activities in school. This indicates the importance of integrating scientific work with children into teacher training. There is also evidence that the appropriate use of science inquiry combined with the use of appropriate technologies can enhance learning. Especially, Microcomputer Based Laboratories (MBL) unique feature of connecting real time data and abstract representation along with their integrated computing power which leads to lack of tedious work are regarded as important tools in science learning. In this study we investigate how primary student teachers design and carry out experiments using MBL. Specifically, sixteen primary student teachers were trained through a 12-week 3 hours duration course. Divided into groups of two the students chose a specific subject area (e.g. mechanics, thermodynamics etc) and were asked to design experimental activities using MBL. Furthermore, they designed a work sheet and applied the developed experimental activities on primary students visiting the university laboratory. Data were collected through 2 questionnaires, an interview, weekly reports and field notes. On the one hand results showed that student teachers acquire a more positive attitude towards experimental teaching mainly through an improvement of content knowledge. On the other hand MBL advantages were partially used leading to a very poor if any connection between the real experiment and the abstract representation. Additionally, the experiments were based on science accuracy and not on students pre-instructional concepts and as a result were science and not necessarily student-oriented.

Keywords: Microcomputer Based Labs, Experimentation, Pre-Service Teachers

INTRODUCTION

Science education has set scientific literacy as a main goal and inquiry as the means to achieve it (Abd-El-Khalick et al. 2004). However international monitoring studies such as TIMMS and PISA indicate that this goal is not fully achieved. In most European countries a gap is revealed between the theoretical value of inquiry teaching and everyday school practice. An active engagement of students in experimentation and as a result becoming familiar with key methods of scientific inquiry is still rather limited (Lunetta, Hofstein & Clough 2007). Practical work is often limited on a manipulation of materials and observables (Abrahams & Millar 2008). Inadequate professional development has frequently been mentioned in the research literature as a reason for not carrying out such activities in school (Loughran, Mulhall, & Berry 2008).

The appropriate use of science inquiry combined with the use of appropriate technologies can enhance learning (Scanlon et al. 2002). Especially, Microcomputer-Based Laboratories (MBL) are regarded as important tools in science learning and that is because of their unique feature to connect, in real time, the experiment data with abstract representation (Sokoloff et al. 2007). MBL supply the necessary tools to make the necessary connections between the domain of objects and ideas in any experimental activity (Figure 1, Tiberghien 2000) faster and more solid. MBLs' lack of tedious work, immediate results, aid of collaboration, understanding of concrete and familiar before advancing to general and abstract, active engagement and constructing personal understanding contributes in better learning results (Redish et al. 1997).

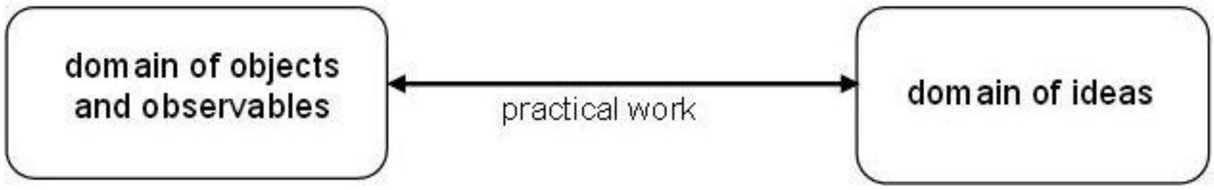

Figure 1. Connection of ideas and objects through practical work. (Tiberghien 2000)

The effect of MBL on primary school students along with the training required concerning the teachers is an area that needs to be further investigated. Based on that, the present study followed a pattern of training in order to record the primary teachers' abilities and difficulties in designing and implementing experimental activities as significant means to foster learning of science contents, experimental skills and methods of science inquiry using MBL. It focuses on pre-service primary teachers since there is certain evidence that primary school teachers are reluctant to teach science due to lack of content knowledge which inevitably leads to lack of the necessary confidence to teach (Appleton 2003). The main research question is:

- How primary student teachers design and put into practice experimental microcomputer-based activities?

METHOD

The research framework

The research framework used is the "Model of Educational Reconstruction" (MER, Duit et al 2012). The model has been developed as a theoretical framework for studies investigating whether it is worthwhile and possible to teach particular science concepts, principles and views of the nature of science. The major aim is to achieve a balance between science content structure and educational concerns when developing teaching and learning sequences. The model consists of three closely interrelated components a) *Clarification and analysis of science content*, b) *Research on teaching and learning*, combining investigations of students' perspectives along with studies on teachers' views and beliefs on science concepts, c) *Design and evaluation of teaching and learning environments,* combining the design of instructional materials, learning activities, and teaching and learning sequences.

Proportional to MER the ERTE Model is a model for designing teacher education (Figure 2; Duit et al. 2012). ERTE comprises the major ideas of the MER. In order to design efficient settings for teacher education it is necessary to investigate teachers' views (their PCK). Further, it is essential to critically clarify and analyze the beliefs on teacher education in the literature. Similarly to MER, in ERTE the process of developing the guidelines is recursive. In the present study the model was adjusted as shown in Figure 3. There is no linear step-by-step process. Instead a holistic approach was followed in which each goal of the training whether it was content knowledge, experimental skills or knowledge of students' ideas etc affected the process of setting MBL experiments.

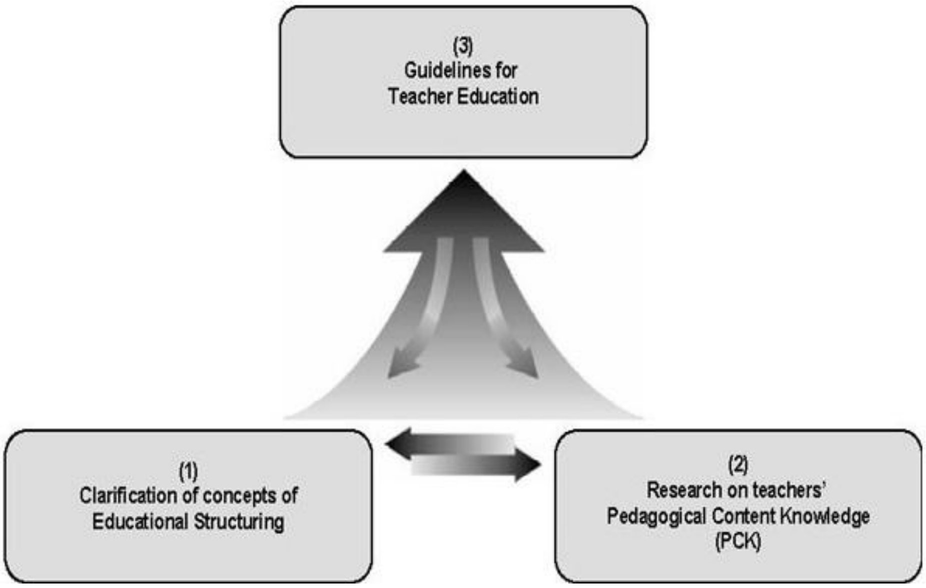

Figure 2. Educational Reconstruction for Teacher Education (ERTE, Duit et al. 2012)

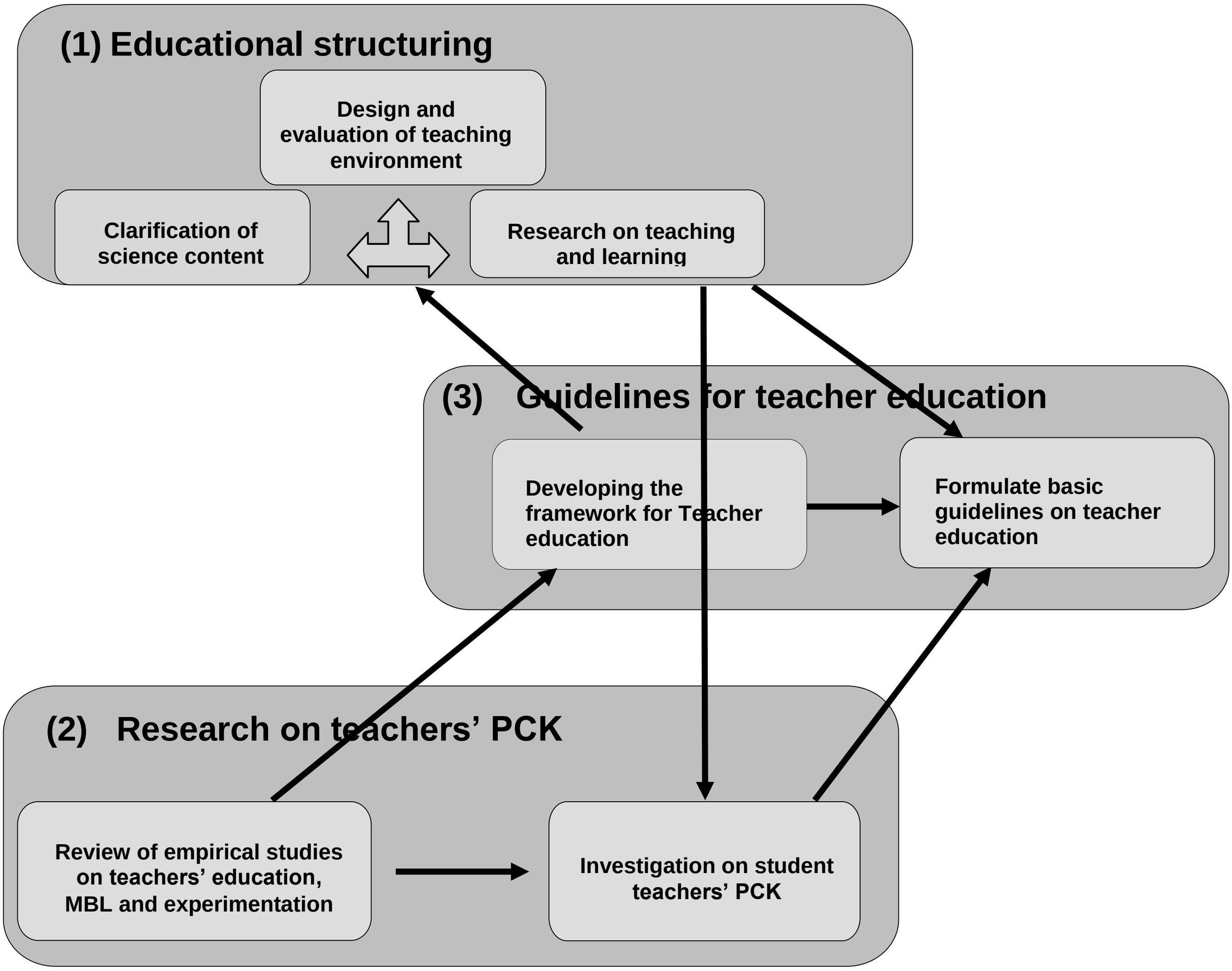

Figure 3. ERTE in the present study

Design of the study

Sixteen primary education student teachers on their graduating year took part in the investigation divided into eight groups of two students. Each group had to design experimental activities among the sections *Mechanics, Optics, Waves, Thermodynamics, Electromagnetism, Energy – Matter, Environment, Chemistry* using PASCO equipment (http://www.pasco.com) and integrate them into an inquiry based approach. The students sustained a good background in pedagogical issues but a limited one in science and mathematics.

Twelve weekly three-hours meetings took place and the whole procedure was divided into three phases (Table 1). During the first (Pre-Lab) they were became familiar with content knowledge, student ideas, curriculum and experimental activities of the school book and inquiry based teaching strategies. They were also asked to find alternative experiments that in their opinion could serve the teaching goals of the section they had chosen. At the end of each meeting they had to deliver a weekly report or task and to note down the sources they used to fulfil their task. On the second (Lab) they recorded the instruments they had on their disposal and developed MBL experiments and corresponding worksheets following the schema: posing scientifically oriented questions, making hypothesis, designing an experiment, making predictions, carrying out the experiment, making observations – collecting data, analyzing and interpreting the data, coming to a conclusion. On the third (Implementation) they made some final adjustments by applying the designed course on fellow student teachers and then discussed the developed experimental activities with four groups of primary school students that visited the university lab. It has to be mentioned that there was no demonstration of the apparatus abilities and no guidelines on what experiments the student teachers should carry out or what to teach. The only limitation was to serve the aforementioned inquiry schema.

Table 1. The phases of developing and implementing experimental activities

Pre-Lab	**Lab**	**Implementation**
Review of the school book Science Content analysis Analysing literature on students perceptions Research for alternative experiments	Registering materials and instrumentation Designing their own experiments	Pilot – application of the designed experiments to their peers Application of the designed experiments to students of class 5 and 6

Data were collected using two questionnaires (one at the beginning and one before the implementation phase), in order to investigate their view and their attitude toward science teaching and experimentation in general and particular towards MBL. Additionally, an interview after the implementation of the activities, students' weekly reports and field notes were analyzed to observe possibilities and difficulties in the process of designing and applying the activities. Due to the explorative character of the study qualitative methods were used to analyze the data (Mayring 2000).

RESULTS

The first questionnaire had questions concerning primary student teachers general attitude towards science, science teaching and experimentation. Furthermore, the areas primary student teachers consider that they need training was asked. The data show that prospective teachers face experiment as a practical application of theory, a way to “make ideas concrete” and not as a way to initiate mental processes for the students. On the questionnaire student teachers underappreciated the goal of “demonstrate scientific concepts” and “creation of scientific ideas” while on the contrary over appreciated “providing concrete experimental learning”. On the domains they feel they need training first is “subject matter knowledge” and second comes the “use of the devices” while “assessment of students” was very low ranked. At the beginning of their training there was an overall insecurity as whether their content knowledge was adequate for teaching science. Indicative:

“I am afraid that student questions will confuse me”

“There are a lot of things about science that I have not understood and therefore can not explain to others”

“I am worried about unpredictable questions that I would not be able to answer”

Primary student teachers succeeded in designing and carrying out experiments using the devices. Furthermore, they developed the necessary worksheet following some basic principles of science inquiry. Each team developed an average of 5 experiments using MBL.

As far as devices are concerned there was limited use of their abilities and they were mainly used in a traditional way. 68% of the experiments are variations of experiments that could have been carried out with traditional measurement instruments. 54% of the experiments used MBL to take simple measurements (e.g. as a thermometer, dynamometer etc) (Figure 4), 12% used simultaneous measurements such as pH and temperature (Figure 5). Graphical representation of data was used in 26% of the experiments (Figure 6). No experiments used the bibliographical mentioned advantage of portability, only once MBL were used in a very slow experiment and once in a very fast one.

Figure 4. Use of the device as a common thermometer

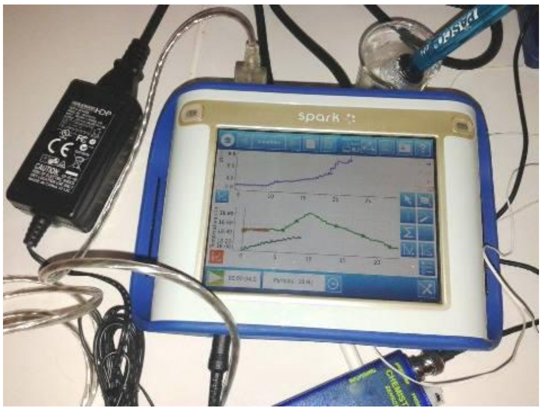

Figure 5. Simultaneous time depended measurement of ph and temperature

Figure 6. Graphical representation of time depended CO_2 concentration in an air tight box during photosynthesis.

Furthermore the real-time display of experimental results and graphs thus facilitating direct connection between the real experiment and the abstract representation were rarely used. In most of the cases the data displayed was analyzed without making any connections to the real experiment. In other words, the interaction between the real experiment and the data displayed is missing. In addition the designed experimental activities were mostly “science” – oriented, i.e. oriented to the scientific content and not necessarily to students needs. Students’ ideas and their learning processes have been taken into little consideration and as a result few experiments intentionally address students’ pre- instructional conceptions.

At the end of their training all students stated that their subject knowledge was improved and that a deeper understanding of the section they chose was succeeded. Their attitude towards science also shifted from negative (14 out of 16 primary teachers at the beginning thought science as “difficult”, “meaningless”, “inconceivable”) to positive. This shift has an impact on their necessary self-esteem to conduct experiments and teach science on later years. Two characteristic excerpts taken from the interviews of students follow:

“The truth is that the hated physics I never managed to understand concepts ... I read endlessly but never understood anything... I think I understood completely everything I dealt with during the present training”

“I was afraid of physics and I hated physics and I was learning everything by heart... this training help me to overcome and understand”

In overall as student teachers mentioned also during the interview the training helped them to overcome their negative attitude towards science and that was because they had a maximum margin of freedom to choose objects, experiments, sources etc. That freedom, in their opinion, had an impact on their self-esteem because during their training they were under the impression (and they actually were) on their own on circumstances similar to the ones they would face in a real classroom.

DISCUSSION AND CONCLUSIONS

The study provided some insights on the way teachers design and put into practice MBL experimental activities. The advantages of the MBL were partially used by the primary student teachers and therefore their designed experiments lacked the immediate feedback that the devices can offer. Furthermore, there was a general misinterpretation of the way MBL work and primary student teachers seemed to perceive data and the experiment monitored by MBL, as two separate parallel running procedures that do not necessarily connect. They could not always appreciate the MBLs' most distinctive feature of displaying real time data.

Their designed activities did not necessarily take into consideration students' perspective. Instead the reverse process took place on several occasions and which was that student teachers developed an activity based on subject knowledge and afterwards they searched for students' ideas it applies to. Their initially concern about subject knowledge seems to drive the student teachers to the process of designing experimental activities.

During their interview the strong connection between the topic of instruction(content) and the media (experimental activities) was confirmed and probably explains their changed view about science since they consider that the whole training reinforced content knowledge. This change can also be attributed to the fact that student teachers developed the experiments with no specific guidance or demonstration of the devices abilities. Instead the whole process was mainly self-driven with minimum interference by the instructors resulting on experiments that combined to some extent a mixture of pedagogical knowledge, learning strategies and content knowledge.

Future trainings should target more directly on integrating students ideas because primary teachers' awareness of the students' perspective does not mean that they base their activities on them. Special attention should be paid to a more extensive use of the MBL abilities by teachers and specifically to the fact that MBL is not a virtual laboratory but on the contrary a real one with extended possibilities. The level of freedom on the one hand should remain high because it affects positively the teacher students' attitude and their knowledge gains.

NOTES

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REFERENCES

Abd-El-Khalick, F., BouJaoude, S., Duschl, R., Lederman, N. G., Mamlok-Naaman, R., Hofstein, A., Niaz, M., Treagust D & Tuan, H. (2004). Inquiry in science education: International perspectives. *Science Education*, 88, 3, 397–419

Abrahams, I., & Millar, R. (2008). Does Practical Work Really Work? A study of the effectiveness of practical work as a teaching and learning method in school science. *International Journal of Science Education, 30*,14, 1945–1969.

Appleton, K. (2003). How Do Beginning Primary School Teachers Cope with Science? Toward an Understanding of Science Teaching Practice. *Research in Science Education* 33, 1-25.

Duit, R., Gropengießer, H., Kattmann, U., Komorek, M., & Parchmann, I. (2012). The Model of Educational Reconstruction–a Framework for Improving Teaching and Learning Science1. In *Science education research and practice in Europe* (pp. 13-37). Rotterdam, Taipei: Sense Publishers.

Loughran, J., Mulhall, P., & Berry, A. (2008). Exploring pedagogical content knowledge in science teacher education. *International Journal of Science Education*, 30, 10, 1301-1320

Lunetta V,N., Hofstein A. & Clough M. (2007)**.** Learning and teaching in the school science laboratory: an analysis of research, theory, and practice, In N, Lederman & S. Abel

(Eds,), *Handbook of research on science education.* (pp. 393-441), Mahwah, NJ: Lawrence Erlbaum.

Mayring, P. (2000). Qualitative Content Analysis. *Forum: Qualitative Social Research* 1,2, 105-114

Redish F.R, Saul J.M., Steinberg. R.N. (1997) On the effectiveness of active-engagement microcomputer-based laboratories. *American Journal of Physics* 65, 45-54

Scanlon, E., Morris, E., Di Paolo, T., & Cooper, M. (2002) Contemporary Approaches to Learning Science: Technologically-Mediated Practical Work. *Studies in Science Education*, 38, 73-114.

Sokoloff, R.D., Laws W.P. & Thornton K.R.. (2007) RealTime Physics: active learning labs transforming the introductory laboratory. European Journal of Physics, 28, 3, 83-94.

Tiberghien, A. (2000). Designing teaching situations in the secondary school. In R. Millar, J. Leach and J. Osborne (Editors): *Improving science education: the contribution of research.*(pp. 27-47) Buckingham, UK: Open University Press.

EXPLORING STUDENT TEACHERS` KNOWLEDGE CONCERNING DIAGNOSTICS IN SCIENCE LESSONS

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Abstract

Diagnostic knowledge is an area which belongs to Pedagogical Content Knowledge (PCK). PCK is especially important for professional teachers and therefore should be one of the central constructs addressed by teacher training. Diagnostic knowledge appears whenever one deals with heterogeneity, models of lesson design and individual support (Buholzer & Zulliger, 2010). For this reason the aim of the present cross-level case study is to determine chemistry student teachers' level of diagnostic knowledge. For the present study, the definition of diagnostic knowledge is based on Jäger (2007) and can be classified into three main dimensions: 1. Conditional Knowledge, 2. Technological Knowledge, 3. Knowledge of Change.

The present paper presents a study with three groups of chemistry student teachers at different points during their university teacher training program. Two of the groups were visited just before they began different modules which combine theoretical and practical elements. But the topic of diagnostics is presented in different ways and with varying intensities in these courses. The third group was visited after finishing all modules. The current study is based on a qualitative research approach examining 65 chemistry student teachers with regard to their knowledge concerning diagnostics in the classroom. Starting with the evaluation pattern developed in this study, the results show that three groups of participants possess some knowledge about diagnostics. However, their personal knowledge levels appear to be quite low and can be described as naive. Finally, knowledge differences between the three groups can also be recognized. Taking the structure of the various seminars into consideration, the results will be presented and discussed here.

Keywords: student teachers` knowledge, diagnostics, qualitative study

THEORETICAL BACKGROUND

The construct of Pedagogical Content Knowledge (PCK) is widely used in science education research. It was mentioned for the first time by Shulman (1986). PCK is specific professional knowledge, which is developed and expanded upon during teacher education and intensively reflected upon during work experience. Such knowledge includes both measuring beginning students' pre-knowledge and explicitly understanding their individual characteristics. This includes how to personally define and diagnose such factors among learners (Loughran, Berry & Mulhall, 2006).

Whenever diagnosis or diagnostic skills are spoken of in the context of school, such concepts are linked to ideas including 1) the handling of heterogeneity (Grossenbacher, 2010), 2) inclusion (Florian & Black-Hawkins, 2011), 3) teaching units (Vogt & Rogalla, 2009), 4) individual support of students (Barke, Hazari & Yitbarek, 2009), 5) diagnosing learning disabilities (Williams, 2013), 6) misconceptions in science education (Barke, Hazari & Yitbarek, 2009), 7) teacher competence (Loughran, Berry & Mulhall, 2006) and 8) with linguistically-sensitive science-lessons (Markic, Broggy & Childs, 2012).

Diagnostics can be performed both pedagogically and psychologically. Psychological diagnosis includes the definition of behavioral disorders, intellectually gifted students and special needs education (Füchter, 2011). Pedagogical diagnosis covers evaluation in the classroom and in school life. Three examples are learning process diagnosis, performance diagnostics and diagnosis of the starting position of learning. Generally speaking, pedagogical diagnostics covers all activities which should optimize the learning process among students. Within the notion of diagnosis, one should systematically differentiate between the object, the method and the target, in order to prevent differences of opinion (Buholzer & Zulliger, 2010). The evaluation of lessons or the diagnosis of school quality belong to both pedagogical and psychological diagnosis. For teachers, the overlap of these two diagnostic areas can be important (Füchter, 2011).

Teachers need to know how to pedagogically diagnose situations in their classrooms in different ways. Klug (2011) illustrates a diagnostic process that can help teachers to make a diagnostic for their classroom.

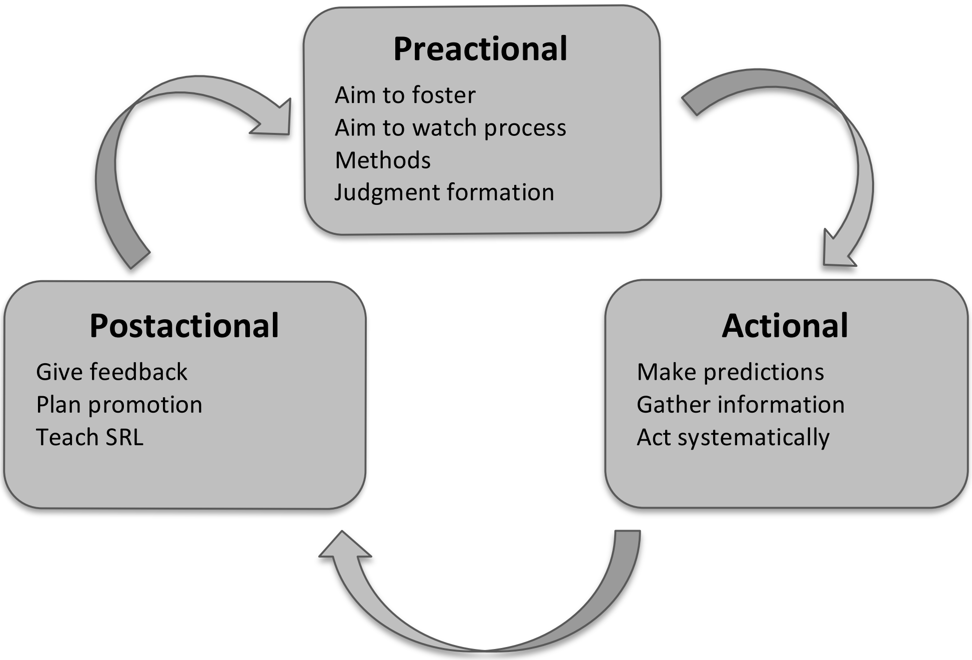

Figure 1: Process model of teachers' diagnostic competence (Klug et al., 2013)

At the beginning of the process the teacher should define the aim of diagnosis. To fulfill this aim, special methods and instruments need to be selected (Preactional phase). Following this comes the Actional phase, in which the data are to be collected. The Postactional phase is the end of the first round, in which a promotional plan is developed and implemented. This cyclical process should be periodically reviewed for its effectiveness and repeated over time. To carry out the different steps and effectively diagnose students, a teacher in general and science teacher in particular needs to have different competences and knowledge (Klug et al., 2013).

Schrader (2013) defines diagnostic competence and focuses on two main statements. First, diagnostic competence is the teacher's ability to successfully cope with the upcoming tasks. Second, Schrader (2013) focuses on the quality of the diagnosis. This is comparable to Jäger's general description of diagnostic competence, where the focus is often on quality (Jäger, 2007). Such views explain why diagnostic competence has mainly been studied in terms of the exactness or correctness diagnosis since the 1970s (Klug, 2011; Perry, Hutchinson & Thauberger, 2008). In contrast, Girmes (2006) views diagnostic competences as learned knowledge about learning, the development of interpersonal relationships and effective use of such knowledge to encourage attendance. This includes using diagnosis to discern opportunities and obstacles facing particular learners in particular situations. Girmes (2006) focuses on the first part of Schrader's description.

Finally, Jäger (1983; 2007) classifies the knowledge of pedagogical diagnostic dimensions:

1. Conditional Knowledge - knowledge of the effects and the possible manifestations of a given survey,
2. Technological Knowledge - the ability to select the most appropriate data collection and analysis methods for diagnostic questions,
3. Knowledge of Change - knowledge development which includes the application of strategies dealing with changing the experiences and behaviors of those involved in the interaction.
4. Competence Knowledge - the diagnostician has the knowledge to be able to answer a specific question. If the teacher does not have it, he must extend his knowledge or include a more competent person to answer the question.
5. Knowledge of the Comparison - knowledge about the classification of behavior with a comparative group.
6. Psychological Diagnostic Competence - the ability to consider the different psychological diagnostic prospects.

The sixth competence is not so important in a school context and this is a global competence for a psychological diagnosis. Furthermore, different models of teachers` diagnostic competence (e.g. Klug et al., 2013) differentiate inadequately between the object and the methodology (von Aufschnaiter et al., 2015). The first three competencies listed by Jäger can be derived from a diagnostic process. In the further aspects of the model it is clearly evident that Jäger (2007) differentiates between the object and the methodology.

Many studies have been limited in their grasp of the diagnostic competence of teachers with respect to teachers' accuracy of judgment. Often (e.g. Partenio & Taylor, 1985; Hoge & Coladarci, 1989; Demaray & Elliot, 1998; Feinberg & Shapiro, 2003; Karing, Matthäi & Artelt, 2011) the correlation between a teacher's judgment and the real occurrence is analysed using less distortion-prone test instruments. It has been shown that teachers can assess the ranking of performance rather precisely, but that individual judgment differs quite widely from what really happened. Bates and Nattelbeck (2001) could show that teachers tend to overestimate the reading performance of students (especially struggling readers). Very few studies have examined the development of diagnostic competence during teacher training and even less have specifically looked at chemistry teachers.

METHODS AND SAMPLE

Development of the above-mentioned competences needs to be started during university teacher training programs. Thus, the focus in the present study is on student teachers of chemistry. From this starting point, three main research questions can be answered:

1. Which diagnostic competence about chemistry classes do student teachers possess at different points of their teacher training?
2. How does the combination of theoretical knowledge and practical experience influence the level of diagnostic competence?
3. How does diagnostic competence differ among student teachers in varying semesters?

Because theories about diagnostic competence in science education are very rare, the following research is based upon open-ended questions. First, chemistry student teachers were asked for general background information about their age, sex, number of semesters studied, etc. Further information was also gathered about their linguistic backgrounds and knowledge of foreign languages. The second part of the questionnaire began with the task "Write an essay about diagnosis in chemistry lessons." The idea to start with an essay was not introduced to influence the participants on this issue in any way, but rather to collect a time-dependent snapshot their first-hand knowledge and beliefs about this topic. The third part of the questionnaire consisted of four questions. Based on the three dimensions of diagnostic competence advocated by Jäger (2007), participants were asked to:

- describe how learning group heterogeneity can affect education.
- describe what methods they would use for diagnoses (e.g. the language level of the child).
- describe what strategies they would use in the classroom to deal with heterogeneity.
- describe how (or if) they would include heterogeneity in their lesson planning.

To help answer the research questions, two university modules were included in the research. What is special about those modules is that both combine theoretical learning with practical phases. Data was collected from a total of 65 student teachers (36 female, 29 male), whose main subject is chemistry combined with either biology or mathematics as their secondary subject. Twenty-two chemistry student teachers in this study were in their fifth-semester. Another 28 were at the beginning of their seventh semester. A total of 15 had already finished both university modules. All of them are native German speakers and have more-or-less comprehensive knowledge of one other language. Seven of the participants have migration backgrounds (Russian, Polish, and Turkish).

The fifth-semester student teachers in this study were not enrolled in either of the university modules at the time of the data evaluation. Instead, they were about to start a module of two parallel seminars with an internship in school. Their task was to diagnose one group of students and to develop lesson plans for further teaching with the help of a mentor in their school. The group in their seventh semester already visited this diagnostics module and was about to start the second one. The third group of student teachers had just finished the relevant (second) module, following by an internship which lasted for 5 months (24 hours a week). They were required to plan, test and develop their own lessons and teaching units. More detail about the structure of the modules is presented in Figure 2 and 3.

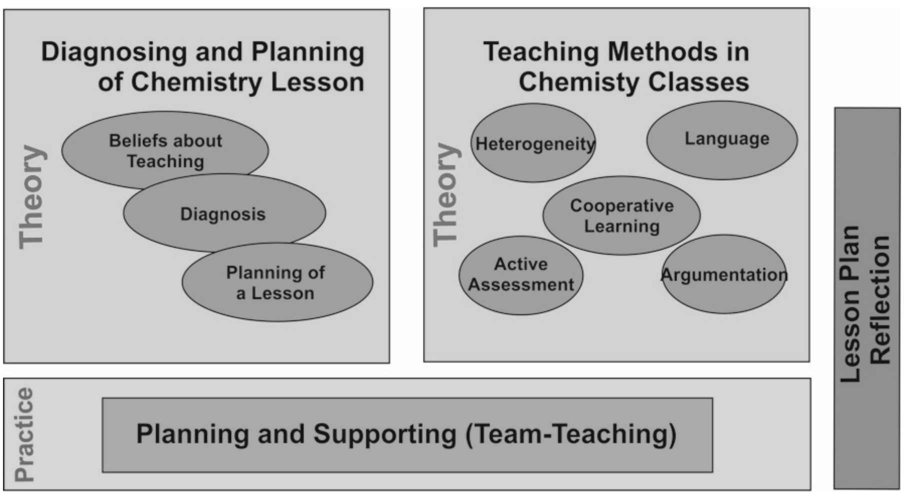

Figure 2: Detail representation of the module "Fachdidaktik 2" involved in this study.

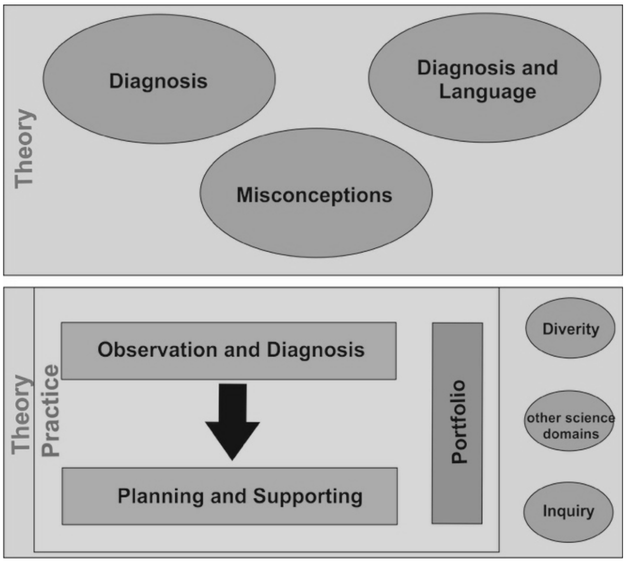

Figure 3: Detail representation of the second modules “Fachdidaktik 4” involved in this study.

DATA ANALYSIS

As mentioned above, research on diagnostic competence is currently under-differentiated and scattered in scope. However, it can still be used as a starting point. Using previous research as a benchmark, data analysis was performed using Qualitative Content Analysis as presented by Mayring (2014) using MAXQDA. The evaluation pattern was collected inductively from the data. Mayring's (2014) quality criteria of qualitative research have been kept: documentation of methods, interpretation safeguards, proximity to the object, rule-boundedness, and communicative validation. From the theory of diagnostic competence presented by Jäger (2007), four competencies could be found in the data: (i) Competence Knowledge, (ii) Conditional Knowledge, (iii) Technological Knowledge and (iv) Knowledge of Change. The coding was done independently by two researchers and inter-agreement as defined by Swanborn (1996) was reached.

RESULTS

Overall there are differences between the groups of student teachers. The data will be presented considering the four categories mentioned above.

- Competence Knowledge: Before they had taken any of the learning modules, almost the half of the student teachers had more negative attitudes toward heterogeneity and diversity in chemistry classes. They viewed it as a problem that needs to be dealt with. Furthermore, the second and the third group didn’t mention this issue at all. With each step forward in the learning process, less student teachers defined heterogeneity as a problem or a challenge. With respect to awareness of the diagnosis process in chemistry classes, the student teachers in the very first group mentioned the need for diagnosis much more often than the more advanced student teachers in the other two groups. Finally, the third group seemed better equipped to see the importance of diagnosis after spending 5 months in a school. These participants could explain exactly what happens while making a diagnosis. Most interestingly, the group of student teachers expressing the highest levels of doubt and insecurity about the meaningful use of diagnosis in the lesson/classroom was the second group.
- Conditional Knowledge: All three groups in this study mentioned students` linguistic skills and content knowledge as a main influence for the heterogeneity in chemistry

classes. Other dimensions of the diversity wheel appear to be unimportant to students in the beginning phases, but become more important after they take part in the practical phases. Thus, the student teachers in the second and the third groups mentioned these dimensions as well. It is interesting that after the first practical phase student teachers think that “no appropriate support of students” is a reason for diversity in chemistry lessons. After the second practical phase non-student teachers write about this problem.

- Technological Knowledge: All of the student teachers in this study are mainly focused on written data collection. Written means any kind of worksheets with different topics or even experiments. The first group of student teachers mainly mentioned that tests as a diagnostic strategy seem unimportant. This group focused more on classroom observation. The second and the third group, however, mentioned that tests are an important strategy for diagnosis. In contrast, observation seems to be viewed as a relatively unimportant tool for diagnosing students during the course of the study.
- Knowledge of Change: This dimension was the most prominent in all three groups of student teachers. The predominate strategy in all the groups was differentiation. Furthermore, data showed that student teachers saw effective teaching and learning time as a factor that needs to be taken more into consideration. The same can be said for the importance of matching worksheets more to the students` needs and about the diversity within the class itself.

CONCLUSIONS AND IMPLICATIONS

Chemistry student teachers in this study appeared to be sensitive to heterogeneity in the classroom and its influence on the learning atmosphere during lessons. On the one hand, they realize that heterogeneity can negatively influence the atmosphere in class and cause disruption. On the other hand, the same heterogeneity can aid in developing the learners' social skills and contribute to a better understanding of different cultures. It is good to see that negative attitudes towards heterogeneity and diversity were not mentioned after the participants had finished all of the modules.

This study shows that the knowledge of change is very pronounced among the student teachers in this study. This aspect had been discussed widely in the seminars, including various possibilities for instituting such changes. For this purpose many ideas borrowed from the literature were incorporated in the seminars.

With respect to technological knowledge, the current study shows that student teachers tend to focus heavily on worksheets and tests. Classroom observation plays a less important role than written assessment in most participants' opinion. We can assume that time factors and time pressure (in particular during internships) forces a focus on worksheets and tests. This means that observations are largely ignored. In this area we need to do more research on the details. We need to find out what happens at school and what exactly the cooperation with a mentor in school looks like.

The most important aspect for us and the further development of university modules is the fact that diagnosis comes too short in the early phases of teacher training. During the first internship participants' focus in school is on various other things. They must prepare and carry out 10 lessons (2 hours a week for 5 weeks), which is a very short, intense period of time. Because this is their first time in school as “teachers”, we can assume that student teachers' attention is pulled in many directions and focused on other happenings within the classroom and school structure. This is one reason why diagnostics falls by the wayside during this experience.

Another important question is to what extent the mentor's attitudes and beliefs toward heterogeneity and diagnostics plays a role with regard to the development of diagnostic competence in teacher trainees. It would appear that two hours a week for only five weeks is not long enough for an internship experience. Just as the intern is getting a feel for teaching, school life, the complexities of being a teacher, etc., it is time to leave school and go back to university. Our finding gives us the impression that student teachers are getting a feel for practical issues, however, they don't seem to have enough time to truly reflect on them and find own ways to deal with them. With this in mind, it may be of help to integrate the lessons found in the international literature for countries where school internships and university teacher training are run in parallel over the entire four-year teacher training process. Then, perhaps, suggestions for the betterment of German teacher training can be made.

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REFERENCES

Barke, H.-D., Hazaari, A., & Yitbarek, S. (2009). *Misconceptions in Chemistry: Addressing Perceptions in Chemical Education*. Berlin: Springer.

Bates, C., & Nettelbeck, T. (2001). Primary school teachers` judgments of reading achievement. *Educational Psychology*, 21, 177–187.

Buholzer, A., & Zulliger, S. (2010). *Die Entwicklung der Diagnosekompetenz bei PH-Studierenden: Eine empirische Studie*. Luzern: Hochschule Luzern.

Demaray, M. K., & Elliott, S. N. (1998). Teachers' judgments of students' academic functioning: A comparison of actual and predicted performances. *School Psychology Quarterly*, 13, 8–24.

Feinberg, A. B., & Shapiro, E. S. (2003). Accuracy of teacher judgments in predicting oral reading fluency. *School Psychology Quarterly*, 18(1), 52–65.

Florian, L., & Black-Hawkins, K. (2011). Exploring inclusive pedagogy. *British Educational Research Journal*, 37(5), 813–828.

Füchter, A. (2011). Pädagogische und didaktische Diagnostik: Eine schulische Entwicklungsaufgabe mit hohem Professionalitätsanspruch. In A. Füchter & K. Moegling (Eds.), *Diagnostik und Förderung Teil I: Didaktische Grundlage*n (pp. 45–83). Kassel: PROLOG.

Girmes, R. (2006). Lehrerprofessionalität in einer demokratischen Gesellschaft: Über Kompetenzen und Standards in einer erziehungswissenschaftlich fundierten Lehrerbildung. *Zeitschrift für Pädagogik*, 51, 14–29.

Grossenbacher, S. (2010). Kompetenz und Professionalität entwickeln. In A. Buholzer & A. Kummer Wyss (Eds.), *Alle gleich – alle unterschiedlich! Zum Umgang mit Heterogenität in Schule und Unterricht* (pp. 162–168). Seelze: Kallmeyer.

Hoge, R. D., & Coladarci, T. (1989). Teacher-based judgments of academic achievement: A review of literature. *Review of Educational Psychology*, 59, 297–313.

Jäger, R. S. (1983). *Der diagnostische Prozeß: Eine Diskussion psychologischer und methodischer Randbedingungen*. Göttingen: Hogrefe.

Jäger, R. S. (2007). Diagnostik. In H. E. Tenorth & R. Tippelt (Eds.), *Beltz Lexikon Pädagogik* (pp. 154–155). Weinheim: Beltz.

Karing, C., Matthäi, J., & Artelt, C. (2011). Genauigkeit von Lehrerurteilen über die Lesekompetenz ihrer Schülerinnen und Schüler in der Sekundarstufe I – Eine Frage der Spezifität?. *Zeitschrift für Pädagogische Psychologie*, 25, 159–172.

Klug, J. (2011). *Modeling and Training a New Concept of Teachers' Diagnostic Competence*. Dissertation [accepted], Technische Universität Darmstadt.

Klug, J., Bruder, S., Kelava, A., Spiel, C., & Schmitz, B. (2013). Diagnostic competence of teachers: A process model that accounts for diagnosing learning behaviour tested by means of a case scenario. *Teaching and Teacher Education*, 30(2), 38–46.

Loughran, J., Berry, A., & Mulhall, P. (2006). *Professional learning: Understanding and developing science teachers' pedagogical content knowledge*. Rotterdam: Sense.

Markic, S., Broggy, J., & Childs, P. (2012). How do deal with linguistic issues in chemistry classes. In I. Eilks & A. Hofstein (Eds.), *Teaching Chemistry – A Studybook* (pp. 131–156). Rotterdam: SENSE.

Mayring, P. (2014). *Qualitative content analysis: Theoretical foundation, basis procedures and software solutions*. Klagenfurt: Beltz.

Partenio, I., & Taylor, R. L. (1985). The relationship of teacher ratings and IQ: A question of bias?. *School Psychology Review*, 14, 79–83.

Perry, N. E., Hutchinson, L., & Thauberger, C. (2008). Talking about teaching self-regulated learning: Scaffolding student teachers` development and use of practices that promote self-regulated learning. *International Journal of Educational Research*, 47, 97–108.

Schrader, F.-W. (2013). Diagnostische Kompetenz von Lehrpersonen. *Beitrag zur Lehrerbildung*, 31(2), 154–165.

Shulman, L. S. (1986). Those who understand: knowledge growth in teaching. *Educational Researcher*, 15(2), 4–14.

Swanborn, P. G. (1996). A common base for quality control criteria in quantitative and qualitative research. *Quality and Quantity*, 30, 19–35.

Vogt, F., & Rogalla, M. (2009). Developing Adaptive Teaching Compentency through coaching. *Teching and Teacher Education*, 25, 1051–1060.

Von Aufschnaiter, C., Cappell, J., Dübbelde, G., Ennemoser, M., Mayer, J., Stiensmeier-Pelster, J., Sträßer, R., & Wolgast, A. (2015). Diagnostische Kompetenz: Theoretische Überlegungen zu einem zentralen Konstrukt der Lehrerbildung. *Zeitschrift für Pädagogik*, 61(5), 738–757.

Williams, A. (2013). A teacher's perspective of dyscalculia: Who counts? An interdisciplinary overview. *Australian Journal of Learning Difficulties*, 18(1), 1–16.

EPISTEMOLOGY AS AN AID IN METACOGNITIVE EXERCISES IN ORDER TO TEACH DIDACTICS OF PHYSICS FOR FUTURE TEACHERS

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Abstract: This paper reports part of the outcomes of a research developed in an undergraduate program designed for physics teachers, in which we constructed a structure for teaching Didactics of Physics. This structure involved, three approaches: physics, sociocultural and technical. It deals with how to educate to understand physics. We worked two specific exercises into the class, involving epistemological topics. The first one consisted in identifying students “epistemological profiles” about the concept of time. The second one, was related to study the meaning of “how to observe” in physics. We start from the hypothesis that future physics teachers need to be educated in criteria that let them to observe the physical world, understanding the importance of the role of the observer in the construction of science knowledge. So, we think that it is possible to guide future teachers to improve their capacity to describe physics systems, talk about its description and discuss their argumentations, in order to learn how to guide their future students in the comprehension about how to do science. We found that, in this case, students did not have awareness on their conceptions about how to observe, neither, about their epistemological profiles, and when they realize that they understand that is easier defining strategies to teach. The research was of qualitative nature based on intervention, observation and content analysis.

Keywords: Didactics of physics, Observing in physics, Epistemological profiles, Physics teaching.

BACKGROUND AND FRAMEWORK

We consider important to orientate future teachers to overcome the vision of didactics of physics beyond a technical understanding. For example, explaining the meaning of physics concepts from epistemological point of view in order to create some criteria to design alternative methodologies to teach, as well as, to develop in the student a comprehension on how to teach in different contexts and with different teaching objectives, based on their major domain and comprehension of physics contents.

This perspective involves investigating didactics processes according to new educational objectives, as suggested by Sanmartí (2002), who presents the necessity to teach different skills to understand phenomena, instead of to teach the absolute truth. We based also on researches of Carvalho & Gil-Perez (1993) and Cachapuz; Praia & Jorge (2002) who demonstrate the need to contemplate in the teaching, aspects of History and Epistemology of Science, with the purpose to consider the reconstruction of the knowledge. For that, we designed, applied and analysed two metacognitive exercises, looking to bring future teachers to reflect on their epistemological profiles, which, we understand to help them to enrich their domain of physics contents and to improve their teaching perspective.

In addition, we assume that people need to be educated to "observe" the physical world, since, in the construction of scientific knowledge and knowledge for the teaching of science is very important the role of the observer, as well as in the way it describes the observation in order to interact and dialogue with the observation of other people who observe the same physical system.

METHOD

This is a qualitative research, since the researchers were involved in the planning and development of the proposal and in the analysis of the relationship between theory and practice. We framed in an active intervention type research, understood in the sense proposed by Chizzotti (2003), who considers the intervention as fundamental to study the phenomenon in face of particular situations produced by investigators, in our case, how to educate future physics teachers based on theoretical foundations. Data were collected among 14 students, taking the seventh semester of an undergraduate program designed for physics teachers, of a public university in the state of São Paulo, Brazil, during the second semester of 2012.

Our research questions were: What kind of activities can help to produce self-recognition by students about their own knowledge of physics? How we can do so based on research results and relating Epistemology and Teaching of Physics? The results were studied using *content analysis* in accordance with the proposal of Bardin (2002), which defines it as a set of techniques that allows the inference of knowledge of communications through quantitative and qualitative indicators. We used also textual discursive analysis in the perspective of Moraes & Galiazzi (2007), who developed techniques intermediate between discourse analysis and content analysis.

RESULTS

Identifying epistemological profiles about concept of time

This first exercise was designed based on Martins & Pacca (2005), who proposed a questionnaire aiming to recognize students' epistemological profiles about the conception of time. We asked these future teachers to write or draw on a blank sheet all they relate to the word "time" and after that, to answer a questionnaire about the existence and nature of time.

Exercise:

1) Write or draw on a blank sheet all you relate to the word "time”

2) Time goes sometimes faster or slower?

3) The passing of time varies from person to person?

4) How do you perceive as time goes on?

5) How do you realize that time passes?

6) How can we check/measure the passage of time?

7) Is there time without clocks? Without humans?

8) Having an hourglass, a mechanic and a digital clock: What is the best? What is the most accurate? How do they Work?

Afterwards, we presented the definitions of epistemological profiles identified by Bachelard for the concept of time, according to Martins and Pacca (2005), in order to identify the presence and the intensity with which each profile occurs on responses from each of the students. These epistemological profiles were:

- Naive realism is characterized by a notion of time essentially charged by subjectivity and selfishness; by the association of time with physical exertion and also, with the distance. Time, at this stage, remains heterogeneous, not being applicable to all objects and movements, it is not yet an "abstract mathematical parameter" there is not a univocal measure of clearly determined time by an appliance. Furthermore, it requires the presence of an individual for counting the time.

- Empiricism imagines a single common time to all objects and movements. Time is homogeneus and is a measurable quantity; it can be determined by measuring apparatus, so it is reduced to the procedures for their measurement. There is always the idea of repetition with a unit that corresponds to own cycle of a periodic physical phenomenon or, a unit arbitrarily imposed on the continuous and uniform flow associated with regular phenomena, not necessarily periodic

- Traditional Rationalism is characterized by the insertion of the time concept as a body of knowledge. The property of this concept is significant within a theory as Classical Mechanics. The rationalist time is independent of referencial system and, in consequence, it is absolute. It is a true abstract mathematical parameter, which participates in the mechanical equations and remains unchanged by a change of coordinates between two inertial systems of reference.

- Surracionalism is characterized from two perspectives, on the one hand, theories of relativity (special and general) who deny the Newtonian absolute time, making the passing of time depending on the adopted framework and the presence of matter. Moreover, thermodynamics and statistical mechanics lead to a new understanding of the concept of time to provide an explanatory approach (probabilistic nature) for the temporal irreversibility.

We analysed with the students, the meaning of the profiles found, creating opportunities for learning at two levels: one, related to deepening in ways to detect their own pre-conceptions; another related to the awareness of how they can rebuild their definitions of time, helping them in a re-construction the meaning of this concept.

Results showed that 46% of undergraduates presented higher intensity of naive realism and 54% of them in surracionalism or concomitant aspects of naive realism, empiricism and rationalism traditional.

The first reaction of undergraduates was the surprise in realizing that most of them had all profiles. However, they get worried to know that some of them had the naive realism profile, even near graduation as teachers. Other future teachers realized that one could live with different epistemological profiles, as long as you have awareness of that.

These results permitted guide a discussion on Bachelard's philosophical school related to the concept of time, which presents a vision of epistemological progress in a parallel way to its development in the history of science, offering an opportunity to contribute to such progress; both, in the thought of future teachers, as well as in their future students. This implies to think the teaching of physics in terms of epistemological commitments with students, identifying the presence of epistemological obstacles to explore their views and to assist them in building other views or improvement thereof.

Results

- 46% of undergraduates presented higher intensity of naive realism and 54% of them in surracionalism or concomitant aspects of naive realism, empiricism and traditional rationalism.
- The first reaction of undergraduates was the surprise in realizing that most of them had all profiles. However, they worried to know that some of them had the naive realism profile, even near graduation as teachers. Other future teachers realized that one could live with different epistemological profiles, as long as you have awareness of that.
- Students reflected about teaching of physics in terms of epistemological commitments to students, identifying the presence of epistemological obstacles to explore their views and to assist them in the construction of other points of view or improvement thereof.
- It was also discussed how to take this result in terms of "conceptual change" in order to bring the student to replace some ideas for others, but instead to contribute to the evolution of his thinking or just contributing students to take conscious about their knowledge, starting with the teacher himself.
- Furthermore, this exercise provided an opportunity to students discussing nature of time, understanding it, not just as a concept, but as a "fundamental ontological category" as Bachelard considered.

Studying the meaning of observation in physics

This exercise was designed from a proposal for "observation" in the classroom by Almeida, Nardi, Bozzeli (2009). Each student received a little branch with several leaves, taken from a tree, and we asked them to observe and describe the object, emphasizing the fact that there were not right answers, but simply answers. Using a dynamic class, we asked all students to read the descriptions of their classmates and noticed aspects that others observed but each one did not. By a dynamics of rotation, in which the class is organized in a circle, each student writes his answer on a sheet and after, everyone gives to the classmate that is on the right, who must list the issues that he did not observe in comparison with his colleague. This is repeated until each author receives the first answer sheet with the annotations of all his classmates.

Finally, we developed a debate about the meaning of “to observe” in relation to what observe, what instruments use, how describe observations, and how to communicate it. We found different observation categories, such as coloring, distribution, size, texture, shape, state of the leaves, and external agents.

- *Coloring (shades of green, brown, with their explanations)*
- *Distribution (symmetry of every branch or paired symmetry of the leaves, distribution parameter, amount of leaves)*
- *Size (dimensions, size and quantity relationships)*
- *Texture (smooth, rough, coarse, fine)*
- *Shape (curves, ellipsoid)*
- *State of the leaves (alive, dead, surviving royal nutrients)*
- *External agents to the sheet (insects, dust, environment)*

The first three categories were noted by most of the group; the last four, for only few undergraduates. But other aspects were mentioned only by a student at a time, with eleven points in total factor that enriched the socialization of observations and leading to an effective collective elaboration of observation, leading them to be aware of aspects that would never have observed individually, if not because another colleague introduced. Also, we realized that certain aspects were not mentioned because they were considered obvious and therefore not described in their observations, generating a discussion of what is observable or not, because what was observable for one person was not for others, and some observers go beyond the object observed by the naked eye. These aspects were:

- *"... Some clearer lines which are the vessels that carry nutrients"*
- *"All have a curved cutting the one end to another by dividing them into two parts. In each of these, there are branches connecting the central curve to the limiting curve of the sheet"*
- *"Looking at the back of the plant we can see a kind of fluff, present both in the leaves and in the stem"*
- *"The point is V"*
- *"... It is apparently real"*
- *"The average roughness number is 12"*
- *"... The leaves are green in color, characteristic given perhaps by the chlorophyll ..."*
- *"... The leaves have a characteristic smell of the woods ..."*
- *"Leaf Design"*
- *"The leaves have ellipsoidal shape with an axis passing through it from end to end; which gives the impression that this axis feeds the sheet "*
- *"The leaves appear to be quite resistant"*
- *"At the center thereof (leaf) is thicker ribs various other thinner”*
- *"... Elliptical shape with its largest diameter, with an approximate size of 10 cm and its smallest diameter of approximately 2.5 cm ..."*

- "... This type of sheet is very common in the driveways of the houses of doctors and small towns"
- "... In of the lower leaves are small holes and including a larger hole, these holes can be caused by insects"

The second part of this exercise was designed in order to deepen with the students the sense of observation of physical systems, differentiating “the observation", "the observables" and "the observer”. We take as a foundation the work of Pessoa Junior (1992), in order to bring the students to deepen the meaning of "observable" when a physics system is not observable to the naked eye. We proposed the next problem: Define in absolute terms (not relative), the limit between "the large" and "the small" in nature.

This was developed in three phases; first, each student had to answer on a piece of paper individually, then groups were organized to discuss their answers and build a consensus or identify differences with their respective argumentation, and thirdly socialization was conducted with the whole group to characterize the types of reasonings and construct answers and explanations collectively under the guidance of professor. Groups answered in this way:

- Group 1: "When we can not observe with a microscopic lenses with the best resolution we can consider a boundary between "large" and "small”. Where the unobservable would be "small" and the observable "large".
- Group 2: "In human perception can be said that the small and large limit is set from the human size scale. So, objects smaller than the human being (our perception) are considered the small, and larger objects of the human perceptions are considered the large”
- Group 3: "We believe that in nature the limits between large and small are in what we can see with the naked eye, for example, what we can observe in nature to the naked eye we consider large, and what we can not see with the naked eye, but we can observe just with measure instruments, is considered small”
- Group 4: "Given X as space, the greatness of X may tend to 0 or infinity. 0 If X is related to an object, we associate it with the smallest sub-atomic particle that man can measure, and infinity we can use the universe, which is expanding continuously, endlessly.

The solution for groups yielded the following results: group 1, related to the great "observable" and the small to the "unobservable"; group 2, large and small related to "human perception" (macroscopic scale); group 3 related large to "observable to the naked eye" and small the "observable if aiding instruments" and; group 4 related the lower limit of the small to the “lowest measurable subparticle" and the upper limit of the great infinity (immeasurable). All these ideas were discussed with the whole group.
This exercise showed that, with the guidance to recognize ways of explaining it is possible to contribute to the (re)construction of the physical concepts they have learned in physics courses, allowing enrich and deepen the body of knowledge that the students will have to teach in their future professional practice. In this case, from an epistemological perspective, deepening the understanding of the relationship between the observer, the observed and the observable.

Results

- In the first part of the exercise, we noted that emerged aspects denoting influence of the context in which they live, knowledge of biology, philosophical questions, artistic skills and applications of mathematics. That allowed us debating about the meaning of observation and the complexity of constructing one description of an object considering all of these aspects, because it requires decisions about the objective of observing and, defining what instrument is more appropriate for observation, language, representation, among other.
- In the second part, in general, all of the students defined the “large” and “small”, in relation to the subject observed or measured. Nobody described an absolute limit between “small” and “large”, confusing "observable" with "visible with a naked eye" and/or "measurable". These responses were inputs for the analysis and discussion with students.
- Using the methodology from the individual reflections and go for group and collective discussions, and backwards, we concluded with the students that "to observe" is not an action developed at a only time, but a process in which it takes clearly have the intention to "observe something". This can help to know the system characteristics to be observed, the theoretical assumptions of observation, observation instruments and enough appropriate language to describe the observation. And therefore, the "observation" is a process that depends on:
  - the properties and intentions of "the observer”. Here it is pertinent to wonder about: What is the intention of observing? What questions will be answered? What theories or problems create the need to observe something?
  - the "instrument or observation methods" so, What instruments allow you to make descriptions, comparisons, deductions? What language appropriately describes what was observed? Which instruments allow observing objects of various kinds?
  - "the observed”, through questions such as: What systems leave be observed without changing their state, because they are observed? What are "measurable" or not? The system containing the observable is open or closed?

  Students realized that is important to know how they understand concepts of physics from epistemological and philosophical points of view in order to think how to teach it.

DISCUSSION AND IMPLICATIONS

- It was possible to guide the future teacher to improve critical sense over their own conceptions; both, on Physics and Physics teaching, through metacognitive exercises, that allowed them discuss aspects as: meaning of “how to observe” physics phenomena; importance of History, Philosophy and Epistemology to help to overcome naïve visions and the re(construction) of their knowledge.

- It was possible also, to guide undergraduates to improve their observation skills of physics systems, from observations that consider the systems' appearance, leading them to observe the relationship between the parts of the system and, reaching the observation of the causes and consequences of the relationship among the parts of the system.

REFERENCES

Almeida, M.J.P.M.; Nardi, R.; Bozelli, F. (2009) A diversidade de interpretações como fator constituinte da formação docente: leitura e observação. *Educar*, Curitiba, n. 34, p. 95-109.

Bardin, L. (2002) *Análise de Conteúdo.* Original publicado em 1977. Tradutores Luís A. Reto e Augusto Pinheiro. Lisboa: Edições 70, 223p.

Cachapuz, A.; Praia, J.; Jorge, M. (2002) *Ciência, Educação em Ciência e Ensino das ciências.* Lisboa: Ministério da Educação, 321p.

Carvalho, A.M.P.; Gil-Perez, D.(1993) *Formação de professores de ciências.* 2.ed. São Paulo: Cortez Editora, 120p.

Castiblanco, O.L. (2013) *Uma estruturação para o ensino de didática da física na formação inicial de professores: contribuições da pesquisa na área.* 2013. 275f. Tesis (Doutorado em Educação para a Ciência). Faculdade de Ciências, UNESP, Bauru.

Chizzotti, A. (2003) *Pesquisa em Ciências Humanas e Sociais.* 6.ed. São Paulo: Editora Cortez, 164p

Martins, A.F.P.; Pacca, J.L.A. (2005) O conceito de tempo entre estudantes do ensino fundamental e médio: uma análise à luz da epistemologia de Gastón Bachelard. *Investigações em Ensino de Ciências* (Online), Porto Alegre - RS, v. 10, n. 3, p. 1-34.

Moraes, R.; Galiazzi, M.C. (2007) *Análise textual discursiva*. Ijuí: Editora Unijuí, 224p.

Pessoa Junior, O. (1992) O problema da medição em mecânica quântica: um exame atualizado. *Cadernos de História e Filosofia da Ciência*, Campinas, série 3, v.2, n.2, p.177-217. Jul-Dez.

Sanmartí, N. (2002) *Didáctica de las ciencias en la educación secundaria obligatoria.* Madrid: Sintesis Educación, 382p.

INQUIRY-BASED TEACHING AND LEARNING OF NATURE OF SCIENCE IN PRIMARY TEACHER EDUCATION

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Abstract: Understanding the nature of science (NoS) is a fundamental part of scientific literacy and a set of skills regarded as vital in the modern world of science and technology. As such, the aspects of NoS are considered as an important part of science education and recent curricular reforms have already taken this into account. In this study the potential of inquiry-based learning activities was investigated in initial primary teacher education. Ten Finnish pre-service primary teachers went through an intervention consisting of two sets of learning activities designed to be explicit about multiple aspects of NoS. Subjects' understanding was measured before and after the intervention using The Views of the Nature of Science – Form B (VNOS-B) – a validated open-ended questionnaire widely used in this area of research. The results are evaluated and discussed from two points of view: (1) understanding before the intervention, and (2) development of understanding both as a population and individually. As a population positive development was seen in all the areas of our framework, but individually some students showed regression, as well. Even though in general positive development was evident, these activities cannot be recommended as the only teaching tool of NoS in initial primary teacher education since the subjects' understanding on average was mediocre at best both before and after the intervention. Finally, implications to teaching and learning NoS in teacher education are discussed.

Keywords: nature of science, inquiry-based science education, initial primary teacher education

INTRODUCTION

Curricular reforms are called for and based on the changes in the surrounding society. As science – especially scientific knowledge and its applications – have taken an ever greater part in our everyday lives and worldviews, understanding of the various aspects of science has become important for not only to those pursuing a career in science but others, too. As a result, recent science education reforms and standards have emphasized the nature of science (NoS) and inquiry-based teaching and learning (IBTL) more heavily than ever before. (see e.g. McComas & Olson, 2002; National Research Council, 2000; 2012; 2013)

Nature of science

According to Lederman, Abd-El-Khalick, Bell and Schwartz (2002) NoS typically refers to "the epistemology and sociology of science, science as a way of knowing, or the values and beliefs inherent to scientific knowledge and its development". There is no single definition of NoS due to the variety of opinions on the limits of NoS. However, in order to introduce the concept of NoS to K-12 education to at least some extent, three questions can be used to select the appropriate NoS content (Lederman, 2006):

1. Is knowledge of the aspects of NoS accessible to students (i.e. can they learn and understand them)?
2. Is there general consensus about the aspects of NoS?
3. Is it useful for all citizens to understand the aspects of NoS?

Using these criteria Lederman et al. (2002) have proposed seven aspects of NoS to be included in the curricula and instruction of K-12 education. Those aspects cover the (1) tentative, (2) empirical, (3) theory-laden and (4) creative and imaginative nature of scientific knowledge, as well as (5) the concepts of scientific law and theory, (6) the social and cultural embeddedness of scientific knowledge and (7) the myth about the often manifested scientific method.

The views of science start to develop early on as children are in contact with the world. Explanations are being developed in accordance with the socio-constructivist models of learning by building on the various experiences within the social and cultural fabric and by reflecting on them (Simina, 2012). Due to the fact that the use of language in the social environment is known to affect conceptions of the nature of science (Zeidler & Lederman, 1989) and that any preconceptions - including misconceptions - are not easy to change due to their nature as a built-in mental structures (Meheut, 2012; Taber, 2005; Taber, 2001), it’s reasonable to claim that NoS should be considered as a crucial part of science education early on – at the levels of early childhood and primary education. In addition, the advanced understanding of NoS has been noticed to support the learning of other elements of science (curricula) (Linn;Sonder;& Butler, 1993) and problems in this area can impede the learning of science.

The benefits of understanding NoS and possessing meta-knowledge about science, scientific processes and the culture of science are various. For example, Driver, Leach, Millar and Scott (1996) have already identified five arguments - Utilitarian, Democratic, Cultural, Moral and Science learning - in favour of teaching and thus developing the understanding of nature of science. Summing up these arguments, understanding is needed to make sense of science, to manage the (science-based) everyday technology, to participate in discussions and decision-making, to see science as a culture of people and to support the learning of science itself.

Inquiry-based science education

Inquiry in the context of science education should be considered as a pedagogical model that includes a variety of pedagogical methods, ideas and objectives and is based on what professional scientist do. Such things include (but are not restricted to) observing, exploring, formulation of scientifically examinable questions, planning research, performing experiments, collecting data or evidence, utilizing results of earlier research, inventing, comparing, evaluating, sharing ideas and observations, communicating both within the scientific community and with the rest of the society (National Research Council, 2000). In science education five essential features can be especially considered (National Research Council, 2000, pp. 24-27):

1. Learners are engaged by scientifically oriented questions
2. Learners give priority to evidence, which allows them to develop and evaluate explanations that address scientifically oriented questions
3. Learners formulate explanations from evidence to address scientifically oriented questions
4. Learners evaluate their explanations in light of alternative explanations, particularly those reflecting scientific understanding
5. Learners communicate and justify their proposed explanations

As a model of the processes of science, inquiry can be considered as a suitable pedagogical choice for discussions *about* those processes (or about doing science, see Hodson, 2014), as well. Such a topic is very much related to the culture of science and has been considered, in addition to the five features of inquiry-based science education, in the development of the activities that have been used in this study and in the other activities of Nanokoulu (www.nanokoulu.net), as well.

Research questions

Our study focused on the knowledge and understanding held by pre-service primary teachers, and thus the research questions were as follows:

1. What are the views of NoS held by Finnish pre-service primary teachers like?
2. How capable is a set of two inquiry-based activities in developing the views of NoS held by Finnish pre-service primary teachers?

The objective of this study was to find out if a minor scale intervention could be capable of developing the participating students' views about the nature of science. In addition, precious knowledge was gained about the views of NoS held by Finnish pre-service primary teachers. Since the data gathering was made as a part of the participants' studies, the activities were also meant to function as demonstrations of IBTL and teaching NoS and thus develop the participants' pedagogical content knowledge.

METHOD

The study was performed during a course on primary school science teaching typically taken by the pre-service primary teachers at the beginning of the second academic year. Out of the original sixteen participants only ten pre-service primary teachers' went through all the phases of the study. The entire data collecting was performed by the second author within one week, and the intervention was implemented during only three classroom hours (90 min + 90 min). Other factors that could significantly influence the understanding of NoS were considered improbable during this short time period.

Views of Nature of Science Questionnaire - Form B

Experimental design involves a planned intervention and tracing its consequences (Green, 2004). The views of NoS held by pre-service primary teachers were measured using an open-ended instrument called The Views of Nature of Science Questionnaire – Form B (VNOS-B). The instrument was chosen due to its coherence with the aforementioned Lederman's framework and its already tested validity (see Lederman;Abd-El-Khalick;Bell;& Schwartz, 2002). There's also a great amount of prior research where the views of similar population of pre-service and in-service primary teachers have been measured using the same instrument (e.g. Akerson;Morrison;& McDuffie, 2006; Bell;Matkins;& Gansneder, 2011; Akerson, Buzzelli, & Donnelly, 2010).

The validity was assumed to apply despite the translation into Finnish, especially since the original English questions were also visible.

Intervention

The intervention consisted of two activities with structured inquiry-based instructions (see Väisänen, 2015). These were called *Fortuna* and *Punch Card*. Both activities were guided mainly with written instructions while the role of the teacher was kept to minimum – mainly answering questions about the instructions. The instructions were designed to be explicit about the aspects of NoS.

Fortuna

The activity called Fortuna is a typical example of black box activities that are common in inquiry-based teaching. In this case the students use equipment designed and built by the first author and study a hidden sample using small metal spheres (see Figures 1a, 1b and 1c). The objective is to try to find out what the sample is like (e.g. material, structure or dimensions). The instructions were designed by the second author (on the basis of the original version by the first author) to go explicitly through all the seven aspects of NoS. Using this

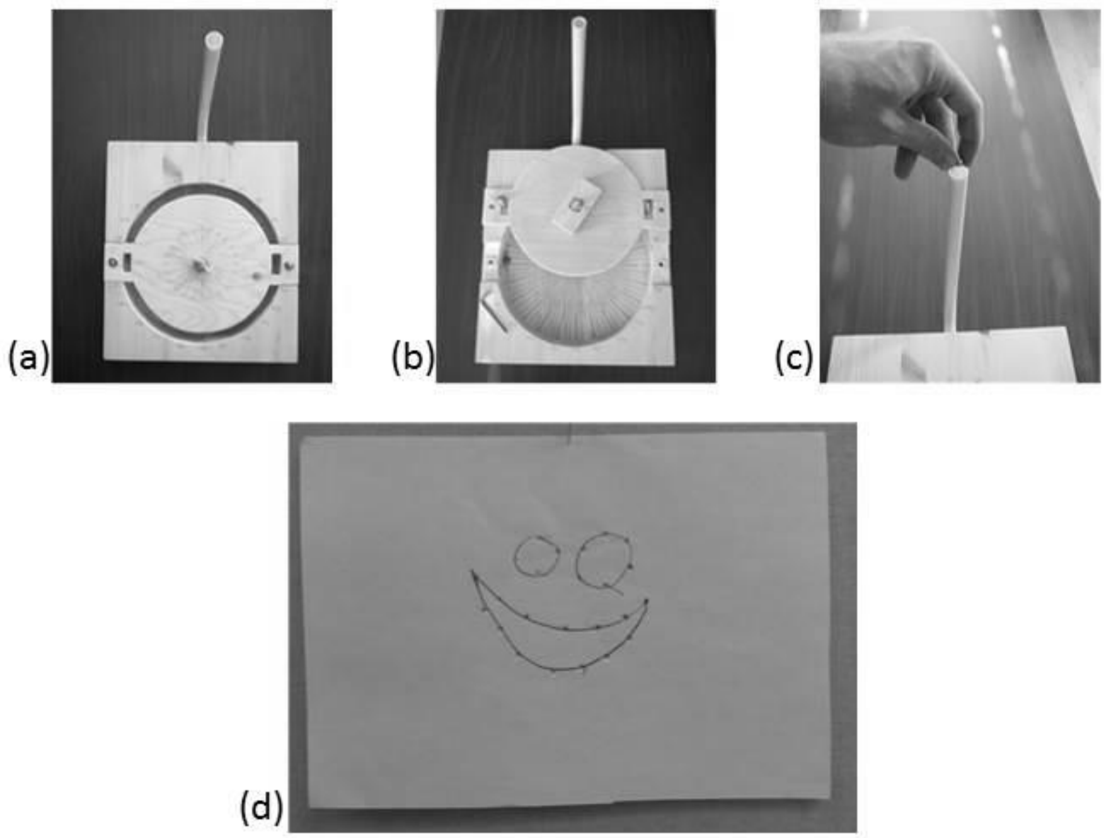

Figure 1 Intervention. The setup of the activity called Fortuna includes (a and b) a wooden base where the sample was hidden and (c) small metal balls. The balls were accelerated in a slope and the results of collisions with the sample (e.g. the collision angles) were examined. (d) Example of a card that was produced and examined in the activity called Punch Card.

simple experiment as a frame the students are guided to think about the scientific questions and methods that could be used, invent possible research settings, make conclusions and communicate about them, discuss the concepts of theory and law, think about and test possible sources of error, and discuss about the role of imagination and creativity in scientific processes.

Punch Card

The activity called Punch Card is based on a similar activity designed by Kelly Hutchinson from the University of Purdue as a part of a teachers' professional development project (NCLT) to demonstrate the basic idea of the scanning probe microscope. The instructions were modified for the new learning objectives – especially to stress the subjectivity of observations and uncertainty inherent to any given measuring equipment. The instructions were designed to go through most of the seven aspects of NoS.

In the activity students are asked to draw an arbitrary figure or shape on a card (or a piece of paper) by punching little holes on it (see Figure 1d). After that the cards are given to other students so they can collaboratively investigate the figures using only their fingers. The cards can be given forward under a table or by other means that avoid visual contact.

Analysis

The participants' answers (in Finnish) to the questions of VNOS-B were compared to the original definitions (in English) of seven aspects of NoS for K-12 education (see Lederman;Abd-El-Khalick;Bell;& Schwartz, 2002). As a result each participant got pre- and

Table 1 The views of aspects of NoS in each profile were labeled either A, D or I

Label		Definition
In agreement	A	All the answers are in agreement with the aspect. Note: An empty answer sheet won't suffice but there has to be claims that are central to the aspect and in agreement with its definition.
In disagreement	D	The answers are in disagreement with the aspect. There are no claims in agreement and there is at least one claim that is clearly in disagreement with the definition of the aspect.
Indefinable	I	The answers are such that it's impossible to say if it's in agreement or disagreement with the aspect. For example, the answers may be too brief or vague.

post-profiles according to their views about each of the aspects before and after the intervention (see **Table 1**).

The first author made two rounds of analysis. The author's lack of experience in using the instrument was considered as a very probable source of error in the analysis - changes were considered probable especially in both the personal interpretations of the definitions of the aspects and the answers. Thus, in addition to the label (A, D, I, X), a brief comment was put down for both documentation and reflection on the second round. These practices turned out very much needed.

RESULTS

Three questions are being especially considered. The first of them deals with the first research question: (1) What is the level of the views before the intervention? The other two deal with the second research question: Are there any changes in the views or understanding either (2) as a population or (3) individually?

Before the intervention

Before the intervention the understanding can be considered to correspond to the general level of pre-service teachers and possibly to that of not-scientifically oriented. The results indicate that the level of understanding about the nature of science is poor (Figure 2). No more than half of the participants held views in agreement with any of the seven aspects of NoS ($M = 3.3$, $SD = 1.2$). The aspect with the most participants (5) having views in agreement was *Theory-laden NoS*.

The distribution of views before the intervention showed big differences between the aspects in the numbers of those labels that are less desired (i.e. D and I). The aspects of *Tentative NoS* and *Creative and Imaginative NoS* had only views in agreement or in disagreement, and had the greatest numbers of profiles labelled as in disagreement (6, 7 and 6 respectively). On the other hand, the aspects of *Empirical NoS, Social and cultural embeddedness* and *Myth of scientific method* all had five profiles labelled as indefinable.

The views in some of the aspects of NoS may be linked to each other. However, the small sample size (10) restrains from making too general conclusions. Spearman correlations were calculated using the pre-test data and such aspects were found to include the *Social and cultural embeddedness* and *Theory-laden NoS* ($r = .633$, $p = .025$), and *Myth of scientific method* and *Scientific theory and law* ($r = .639$, $p = .023$).

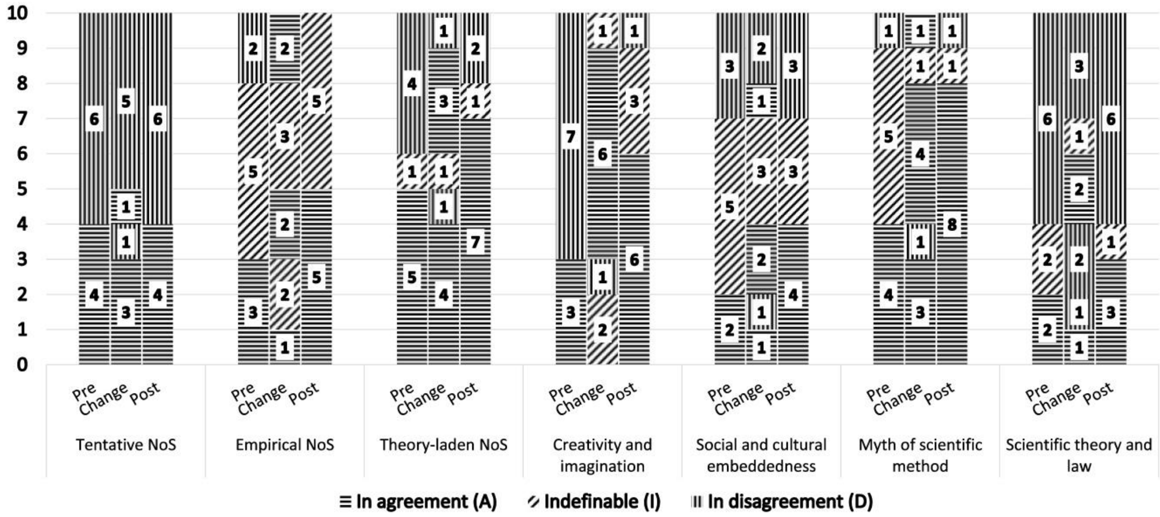

Figure 2. Changes can be seen between pre- and post-tests. Individually some profiles are noticed to change even from A to D (Pre vs Change). However, in none of the aspects the post-results were worse than the pre-results.

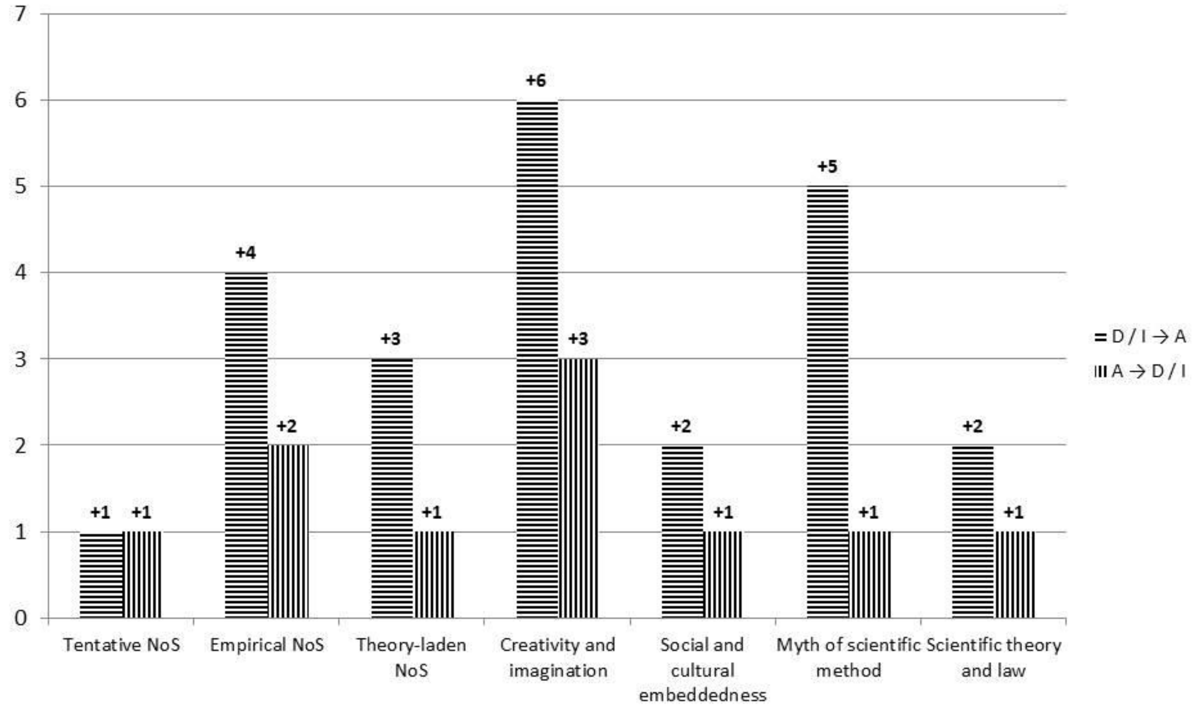

Figure 3. Individual participants went through different types of changes. Negative changes took place in every aspect of NoS but positive changes were more numerous.

Changes in the views

Changes in the views of different aspects were examined both as a population and individually. Examination as a population means that only the average development is considered (Figure 2: Pre vs Post), while individual examination means that the individual changes, say from the category D to the category A, are paid attention to (Figure 2: Pre vs Change; Figure 3). Such an examination was considered relevant since it can reveal educationally relevant traits about the nature of individual changes in understanding NoS.

In general a positive trend could be seen in the results. As can be seen in the Figure 2, the number of views in agreement remained the same or increased (M = 2.0, SD = 1.3). At the same time decrease could be seen in the categories of both indefinable (M = -0.6, SD = 2.2) and in disagreement (*M* = -1.4, *SD* = 2.3). The views were in agreement with the framework especially in the aspects of *Myth of scientific method* (8), *Theory-laden NoS* (7) and *Creativity and imagination* (6). Meanwhile, the views were in disagreement especially in the aspects of *Tentative NoS* (6) and *Scientific theory and law* (6), where the number of profiles in category D was even greater than those of categories A and I together.

In a more general sense, the number of positive changes (considered as the change from either of the undesired categories, D or I, to the desired category of A) surpassed the number of changes in the other direction by almost a factor of two (*M* = 1.9, *SD* = 1.4*)* *(*Figure 3). However, individual undesired changes (from A to D or I) were observed in all of the seven aspects (Figure 2). All in all, the number of views in agreement is still far from perfect (*M* = 5.3, *SD* = 1.8).

DISCUSSION AND CONCLUSIONS

Unfortunately and due to the small sample size and the lack of inter-rater reliability check, the significance of any findings can be considered suggestive at best. However, some general lines can be seen and they seem to be in accordance with previous findings that are discussed within the academic discipline.

The views of pre-service primary teachers

The pre-service teachers' views of NoS and the level of understanding before the intervention were unfortunately in accordance with the results of many earlier studies where the views and understanding were found to be simple, naive, inadequate or weak (e.g. Akerson;Morrison;& McDuffie, 2006; Iii;Hand;& Prain, 2002; Bell;Matkins;& Gansneder, 2011; Abd-El-Khalick & Akerson, 2009). Less than half of all the labels given in this study were I - in agreement with the definitions - meaning that more than half of the views held by pre-service primary teachers about the nature of science may be disordered, confused, non-existent or in direct contradiction to the academic consensus. Considering only the dichotomy of desirable (in disagreement) and undesirable (in disagreement or indefinable) views, the understanding was especially week in the aspects of *Social and cultural embeddedness*, *Scientific theory and law* and *Creativity and imagination.* This means that in addition to the concepts of scientific law and theory, especially unfamiliar or poorly understood was the idea of scientific knowledge being the result of creative and imaginative people living and working in an environment limited by the surrounding time and place.

Views in disagreement with the framework were measured especially in the aspects of *Tentative NoS*, *Theory-laden NoS* and *Scientific theory and law.* Since the label D requires clear and well-articulated views, these findings propose at least three things that need closer examination in the future: (1) the aspects have not been brought up during the students' educational path and the flawed views have been formed in other circumstances, (2) the aspects have been brought up but the instruction has been unclear enabling misinterpretations or (3) the aspects have been introduced in a flawed manner from the very beginning (e.g. emphasizing the absolute objectivity of a scientist).

Despite the weak understanding before the intervention the students might still have had advanced views of the nature of research and knowledge in some other disciplines. In addition, they might have such views about science *in general* - beyond natural sciences - and only fail in applying that knowledge in a deductive manner. This assumption is supported by examination of the curricular documents of teacher education where the nature of educational, historical and mathematical knowledge or research is included in the participating pre-service teachers' precursory studies (see Department of Teacher Education, University of Jyväskylä, 2010; 2012). Such context-bound or situated nature of cognitive functions are still somewhat debated within the scientific community but nevertheless supported by research results and findings (see Brown;Collins;& Duguid, 1989; Perkins & Salomon, 1989; Duschl, 2008; Abd-El-Khalick F. , 2001). Closer empirical look at the context-bound or situated nature of learning NoS is suggested.

Development in the understanding of NoS

Changes in understanding were examined both as a population and individually. As a population the understanding developed - deepened, harmonized or got corrected - in all of the aspects of NoS but especially in the aspects of *Myth of scientific method* and *Creativity and imagination.* Thus it was learned that in addition to the various conventions of support, the development of scientific knowledge requires creativity and imagination.

Despite the generally observed development and increased number of views in agreement with the framework after the intervention – especially in the aspects of *Myth of scientific method* (8/10) and *Theory-laden NoS* (7/10) – on average only half of the participants held advanced views (i.e. in agreement) of NoS even after the intervention. In addition, the development can turn out to be only temporary since the longevity of such gains has been previously observed to correlate with the level of understanding (Akerson;Morrison;& McDuffie, 2006). A longitudinal follow-up study would be needed to estimate the ultimate usefulness of the intervention as a part of teacher education.

Finally, there's no guarantee that any sort of positive changes in understanding would lead to any changes in the planning or executing of teaching practice or advances in the understanding of the teachers' pupils. However, the inclusion of NoS in the teaching plans already during the initial teacher education has been suggested to solidify and thus help any gains to be retained (Akerson;Morrison;& McDuffie, 2006). Studying the impact of understanding NoS in these areas would be a well-justified next step.

Developing NoS education

Considering the results of this study, the learning activities that were used can be considered suitable to teaching NoS in initial primary teacher education. However, negative changes (from class D to I or A) are found in every aspect of NoS and the level of understanding on average is low even after the intervention. In consequence, instructional factors such as reflection and teacher guidance should be additionally implemented as suggested by earlier research (e.g. Akerson;Hanson;& Cullen, 2007; Scharmann;Smith;James;& Jensen, 2005; Schwartz;Lederman;& Crawford, 2004; Abd-El-Khalick & Akerson, 2004; Lakin & Wellington, 1994; Abd-El-Khalick & Lederman, 2000) in order to take the individualistic nature of learning better into account. Other instructional elements considering the history or philosophy of science might be useful but the benefits are still somewhat unclear and under discussion (see Solomon;Duveen;Scot;& McCarthy, 1992; Abd-El-Khalick & Lederman, 2000; Brush, 1974).

REFERENCES

Abd-El-Khalick, F. (2001). Embedding Nature of Science Instruction in Preservice Elementary Science Courses: Abandoning Scientism, But... *Journal of Science Teacher Education, 12*(3), 215-233.

Abd-El-Khalick, F., & Akerson, V. (2009). The influence of metacognitive training on preservice elementary teachers' conceptions of nature of science. *International Journal of Science Education, 31*(16), 2161-2184.

Abd-El-Khalick, F., & Akerson, V. L. (2004). Learning as conceptual change: Factors mediating the development of preservice elementary teachers' views of nature of science. *Science Education, 88*(5), 785-810.

Abd-El-Khalick, F., & Lederman, N. G. (2000). Improving science teachers’ conceptions of nature of science: a critical review of the literature. *International Journal of Science Education, 22*(7), 665-701.

Abd-El-Khalick, F., & Lederman, N. G. (2000). The influence of history of science courses on students' views of nature of science. *Journal of research in science teaching, 37*(10), 1057-1095.

Akerson, V. L., Buzzelli, C. A., & Donnelly, L. A. (2010). On the nature of teaching nature of science: Preservice early childhood teachers’ instruction in preschool and elementary settings. *Journal of Research in Science Teaching, 47*(2), 213–233.

Akerson, V. L., Hanson, D. L., & Cullen, T. A. (2007). The influence of guided inquiry and explicit instruction on K–6 teachers’ views of nature of science. *Journal of Science Teacher Education, 18*(5), 751-772.

Akerson, V. L., Morrison, J. A., & McDuffie, A. R. (2006). One course is not enough: Preservice elementary teachers' retention of improved views of nature of science. *Journal of Research in Science Teaching, 43*(2), 194-213.

Bell, R. L., Matkins, J. J., & Gansneder, B. M. (2011). Impacts of contextual and explicit instruction on preservice elementary teachers' understandings of the nature of science. *Journal of Research in Science Teaching, 48*(4), 414-436.

Bell, R. L., Matkins, J. J., & Gansneder, B. M. (2011). Impacts of contextual and explicit instruction on preservice elementary teachers’ understandings of the nature of science. *Journal of Research in Science Teaching, 48*(4), 414–436.

Brown, J. S., Collins, A., & Duguid, P. (1989). Situated cognition and the culture of learning. *Educational researcher, 18*(1), 32-43.

Brush, S. G. (1974). Should the History of Science Be Rated X? The way scientists behave (according to historians) might not be a good model for students. *Science, 183*(4130), 1164-1172.

Department of Teacher Education, University of Jyväskylä. (2010). Opettajankoulutuslaitoksen opetussuunnitelma 2010-2013. Retrieved October 19, 2014

Department of Teacher Education, University of Jyväskylä. (2012). Opettajankoulutuslaitoksen opetusohjelma 2012-2013. Retrieved October 19, 2014

Driver, R., Leach, J., Millar, R., & Scott, P. (1996). *Young people’s images of science.* McGraw-Hill International.

Duschl, R. (2008). Science education in three-part harmony: Balancing conceptual, epistemic, and social learning goals. *Review of research in education, 32*, 268-291.

Green, D. P. (2004). Experimental design. In M. S. Lewis-Beck, A. Bryman, & T. F. Liao, *The SAGE Encyclopedia of Social Science Research Methods* (pp. 355-357). Thousand Oaks, CA: Sage Publications.

Hodson, D. (2014). Learning science, learning about science, doing science: Different goals demand different learning methods. *International Journal of Science Education, 36*(15), 2534-2553.

Iii, J. A., Hand, B., & Prain, V. (2002). Assessing explicit and tacit conceptions of the nature of science among preservice elementary teachers. *International Journal of Science Education, 24*(8), 785-802.

Lakin, S., & Wellington, J. (1994). Who will teach the 'nature of science'?: teachers' views of science and their implications for science education. *International Journal of Science Education, 16*(2), 175-190.

Lederman, N. G. (2006). Syntax of nature of science within inquiry and science instruction. In L. B. Flick, & N. G. Lederman (Eds.), *Scientific inquiry and nature of science* (pp. 301-317). Springer.

Lederman, N. G., Abd-El-Khalick, F., Bell, R. L., & Schwartz, R. S. (2002). Views of nature of science questionnaire: Toward valid and meaningful assessment of learners' conceptions of nature of science. *Journal of Research in Science Teaching, 39*(6), 497-521.

Lederman, N. G., Schwartz, R. S., Abd-El-Khalick, F., & Bell, R. L. (2001). Pre-service teachers' understanding and teaching of nature of science: An intervention study. *Canadian Journal of Science, Mathematics and Technology Education, 1*(2), 135-160.

Linn, M. C., Sonder, & Butler, N. (1993). How Do Students Make Sense of Science? *Merrill-Palmer Quarterly, 39*(1), 47-73.

McComas, W. F., & Olson, J. K. (2002). The nature of science in international science education standards documents. In W. F. McComas (Ed.), *The nature of science in science education* (pp. 41-52). Netherlands: Springer.

Meheut, M. (2012). Preconceptions and Learning. In N. M. Seel, *Encyclopedia of the Sciences of Learning* (pp. 2662-2664). Springer US. Retrieved December 10, 2015, from http://link.springer.com/referenceworkentry/10.1007%2F978-1-4419-1428-6_1850

National Research Council. (2000). *Inquiry and the National Science Education Standards: A Guide for Teaching and Learning.* Washington, DC: The National Academies Press.

National Research Council. (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas.* (H. Quinn, H. Schweingruber, & T. Keller, Eds.) Washington, DC: The National Academies Press.

National Research Council. (2013). *Next generation science standards: For states, by states.* Washington, DC: The National Academies Press.

Perkins, D. N., & Salomon, G. (1989). Are cognitive skills context-bound? *Educational researcher, 18*(1), 16-25.

Scharmann, L. C., Smith, M. U., James, M. C., & Jensen, M. (2005). Explicit reflective nature of science instruction: Evolution, intelligent design, and umbrellaology. *Journal of Science Teacher Education, 16*(1), 27-41.

Schwartz, R. S., Lederman, N. G., & Crawford, B. A. (2004). Developing views of nature of science in an authentic context: An explicit approach to bridging the gap between nature of science and scientific inquiry. *Science education, 88*(4), 610-645.

Simina, V. K. (2012). Socio-constructivist models of learning. In N. M. Seel, *Encyclopedia of the Sciences of Learning* (pp. 3128-3131). Springer US. Retrieved December 10, 2015, from http://link.springer.com/referenceworkentry/10.1007/978-1-4419-1428-6_882

Solomon, J., Duveen, J., Scot, L., & McCarthy, S. (1992). Teaching about the nature of science through history: Action research in the classroom. *Journal of Research in Science Teaching, 29*(4), 409-421.

Taber, K. S. (2001). The mismatch between assumed prior knowledge and the learner's conceptions: A typology of learning impediments. *Educational Studies*, *27*(2), 159-171.

Taber, K. S. (2005). Learning Quanta: Barriers to Stimulating Transitions in Student Understanding of Orbital Ideas. *Science Education, 89*(1), 94-116.

Väisänen, M. (2015). Developing pre-service primary teachers' understanding of science in society via inquiry-based science education projects – Pre-evaluating the projects. *Manuscript submitted for publication.*

Zeidler, D. L., & Lederman, N. G. (1989). The effect of teachers' language on students' conceptions of the nature of science. *Journal of Research in Science Teaching, 26*(9), 771-783.

ESTABLISHING SCHOOL UNIVERSITY PARTNERSHIPS TO TEACH SCIENCE - DOES WHAT WORKED FOR US WORK FOR YOU?

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Abstract: Concerns over the quality and amount of science teaching in Australian primary schools has led to a concentration of research on the methods of delivery of science education. There is a growing interest in both Australian and International contexts on building teacher knowledge and confidence to teach science, how science is taught at the primary school level and also how pre-service teachers are prepared to teach science. The Science Teacher Education Partnerships with Schools (STEPS) project is one response to these concerns. The STEPS project is a collaboration of five Australian universities that each independently set-up their own school-based partnership approaches with schools to deliver their science education programs. Each university aimed to provide pre-service teachers with the genuine experience of teaching science while being supported by university teaching staff. The project has drawn on feedback from pre-service teachers, teachers, principals and teacher educators involved at the five universities to examine the prevailing practices and led to the development of a set of tools and process, referred to as the Interpretive Framework (IF) (Hobbs et al. 2015). The IF describes how to create and maintain effective partnerships with schools, based on this research. This current paper reports on a survey conducted in 2014 which aimed to feedback from teacher educators across Australia to explore the extent to which school-based teaching opportunities in science for PSTs were in use across the country and to identify the range of approaches and theories driving their practices. Some respondents were followed up for interview and key factors were analysed and reported here. These data will be used to further refine the IF.

Keywords: school-based science education, teacher educators, partnerships

INTRODUCTION

There is long standing concern about the importance of STEM subjects for national prosperity (Office of Chief Scientist, 2014). Many of the issues related to science flow from the learning experiences of students in schools, as other studies have reported, students are 'turned-off' science in the middle years of schooling, and in the primary years, science is often approached in a disconnected fashion or not at all. Thus for many young people science is seen as irrelevant to their lives (Tytler, 2007), which has led to a fall in the number of students enrolling in science in later years (Keys, 2005; Tytler, Osbourne, Williams, Tytler, & Cripps Clark, 2008).

In secondary schools, one consequence of declining enrolments in senior science subjects is that fewer teachers qualified to teach science are available, which has resulted in a growing trend, reported internationally, of teachers who are not formally qualified in the subject teaching science "out of field" (Hobbs, 2013; Hobbs & Törner, 2014). Studies have also shown that the development of children's understandings is fundamentally tied to their teacher's abilities (Darling-Hammond, 2000), so a teacher's capacity to teach science is critical to the student experience.

Additionally, many primary teachers lack confidence and content knowledge to teach science effectively (Akerson, 2005; Hackling, 2006; Tytler, 2007) and when this is combined with an increasingly "crowded curriculum", dominated by literacy and numeracy concerns (Kenny, 2009), the temptation for primary teachers is to avoid teaching science or to adopt inappropriate teaching strategies from other disciplines to compensate for a lack of science pedagogical content knowledge (Appleton, 2003).

Research indicates that authentic science teaching experiences build primary PST confidence to teach science (Howitt, 2007); and more specifically, programs designed around PSTs teaching science in local schools can be an effective form of professional development (PD) for the teachers involved (Jones, 2007; Kenny, 2009, 2010, 2012; Murphy, Beggs, Carlisle & Greenwood, 2004). In secondary schools there is growing international evidence of professional development programs being designed to support secondary teachers teaching science and mathematics "out of field" (Hobbs & Törner, 2014; Kenny & Hobbs, 2015).

Within teacher education, the practical teaching experience in schools is supposed to help pre-service teachers (PSTs) link educational theory with practice by providing authentic professional learning opportunities to implement the theoretical learning at university, however universities report little control over what PSTs in particular teach while on practicum (McCaleb, Borko, & Arends, 1992). Given the discussion above, in relation to science, these issues become more pronounced as many primary PSTs reported having little or no opportunities to teach science, or observe it being taught, during their normal teaching practicum (Kenny, 2010). This also relates to growing criticism that university teacher education programs are unable to bridge the theory-practice gap (Korthagen, 2001; Darling-Hammond, 2006; SCEVT, 2007; Srikanthan & Dalrymple, 2002). McIntyre, Byrd, & Fox (1996:174) described effective practical teaching experiences as ones in which university coursework is integrated, and includes mentoring, reflection and professional learning (PL) for the supervising teachers.

In Australia there has been persistent criticism of the quality of teacher education, with a number of government reports calling for improvements to teacher education (DEEWR, 2003; DEST, 2003; SCVET, 2007; TEMAG, 2014), to develop "classroom ready teachers". Each of these reports has called for stronger partnership arrangements between schools and universities to address the theory practice gap. In Europe, Alake-Tuenter, Biemans, Tobi, Wals, Oosterheert & Mulder (2012) reviewed current literature on competencies required by primary teachers and recommended that PSTs "need mentoring and support within the context of their internship" and that "[s]trong partnerships between teacher training institutions and primary schools might contribute to achieving this goal" (p.27).

In relation to improving science education, this implies opportunities for PSTs to experience authentic science teaching experiences and mentoring in science may need to be created to supplement the normal practical teaching experience. This paper advocates and explores the extent of the use school-based approaches in Australian science education programs to address the problems outlined. Research on primary science teacher education provides evidence of the effectiveness of school-based approaches for preparing PSTs to teach science (Jones, 2008; Kenny, 2010; 2012) and led to the establishment of the STEPS Project (www.stepsproject.org.au), which grew out of the teacher education programs in five Australian universities. These universities had independently developed school-based approaches to teaching primary science which emphasised the importance of the expertise of science teacher educators in fostering the development of the PSTs confidence to teach science, shaping the PSTs' experiences and encouraging them to reflect deeply to make explicit connections between theory and practice.

The range of approaches to teaching science at each university enabled the development of case studies that identified key factors that made school-based approaches effective and led to development of an *Interpretive Framework (IF)* that captured the key characteristics of school-university based partnerships for the preparation of PSTs to teach science. The value of school-based approaches in science was later validated by feedback from PSTs, teachers, principals and teacher educators (Kenny, Hobbs et al., 2014; Kenny, Redman et al., 2014). This paper considers further data recently collected by the STEPS project from science teacher educators in Australia. Indeed, our belief is that the *IF* has a more general applicability, beyond science education, and will assist the establishment, extension or evaluation of other educational partnership arrangements.

METHODOLOGY

As an emergent project, STEPS has used a mixed methods approach to the research. Initially drawing on our own experiences and research to develop case studies. This was followed with pre and post questionnaires and interviews of participating students, teachers and principals to inform the development of the *IF*. In 2014, the project team sought feedback from science teacher educators outside of the project to further validate the *IF*.

The *IF* was presented for discussion at a number of national and international conferences during 2014-2015 (Hobbs et al. 2013; 2014; 2015; Jones, Hobbs, Gilbert, 2014; Hobbs & Kenny, 2015; Kenny, Redman et al., 2014; Hobbs &Jones, 2015; Kenny and Hobbs, 2015) and was progressively revised in response to the feedback received. The latest version of the *IF* can be found on the STEPS website (also see Hobbs et al., 2015).

In this paper, we will report on the results of an email questionnaire and follow-up interviews with science teacher educators, designed to gain a better understanding of the extent to which school-based approaches are currently used in science teacher education programs around Australia, and to explore the nature of these arrangements to further inform the *IF*. In 2014, a survey was emailed to science teacher educators to compile a database of the range of school-based approaches currently in place in the science education programs at each institution and the nature of the partnership arrangements. Those science teacher educators who reported using partnerships to facilitate primary school science teaching were also asked about their motivations for using partnerships, how their school-university partnerships were organised and the extent to which the partnerships were embedded within their practices. Those science teacher educators who reported not using school-university partnerships were asked to discuss why they chose not to do so.

RESULTS AND DISCUSSION

A total of 75 emails were sent to science educators at all Australian universities with 25 responses received to the questionnaire (Table 1). This email incorporated four questions seeking initial information about the teacher educator's science education programs and their use of school-based approaches. Fourteen academics were later interviewed, between September 2014 and December 2014. When six academics from STEPS are included, the dataset comprises feedback from 40 science teacher educators, drawn from 26 (66.7%) of Australia’s 39 universities, implying the sample is likely to be highly representative. Of the respondents, 15 (37.5%) reported they did not include a school-based teaching component and 23 (57.5%) described some form of school-based component in their science teacher education programs while 2 (5%) described professional development programs for teachers as opposed to pre-service programs.

Table 1: Summary of dataset

Number of email questionnaires sent	75
Number of responses to the survey	25
Number of interviews conducted	14
Number of written responses from the STEPS project team, all working in school-based partnerships	6
Total number of academics who responded to the survey and/or interviews (N) (Including STEPS academics)	38
Number of science teacher educators who reported using some form of a school-based approaches (excluding STEPS academics)	17(53%)
Number of science teacher educators who reported no use of school-based approaches (excluding STEPS academics)	15 (47%)
Total number of Australian universities represented in the data sample (percentage of all Australian universities)	26 (66.7%)

Two groups of semi-structured interviews were developed: one for science teacher educators using a school-based approach and one for those who were not. The questions concerned five key themes: the prevalence of any school-based partnership model being employed; the theories that underpin their practice; the characteristics of the school-base approach; how the teacher-educators sustain and manage the program, or what would be needed to commence a partnership and; what blockers and challenges are perceived to sustain or commence a partnership.

The data reveals considerable variation in the nature of the school-based approaches used which is summarised in Table 2. It indicates that the degree of involvement of PSTs with schools ranged across the programs from no contact, to teaching some one-off science activities at special science events, through to a deep engagement involving collaboration between the PSTs and class teachers to deliver a science unit. This variation in “scope” of the involvement of the PSTs is outlined in Table 2 below, and is represented as five levels (0-4) designed to indicate the depth of PST involvement in teaching science in schools. For example, at the lower end, this involved 5 universities at which PSTs conducted a day of science activities for students from local schools. On the other hand, science teacher educators from 5 universities reported that their PSTs participated in fully integrated programs and worked with a class and their teacher to teach science over a period of several weeks:

> *The students work with the same group of children over the full session (8-9 weeks). In science and technology … in the first six intensive weeks the students cover five topics. The teachers choose one of the topics for their children and our students design four remaining lessons that they present and evaluate using an inquiry based approach with their small group of children.*
> *(Lila)*

Table 2: Indicative scope of the school-based science component. (Note the numbers in brackets are inclusive of the STEPS academics.)

Scope	Description of the science learning opportunities for PSTs from the school-based components	No. and proportion of respondents	
0	No school-based component or ad hoc arrangements	15	(37.5%)
1	Opportunity for PSTs to teach science activities (e.g. "Science Fair")	5	(12.5%)
2	Opportunity for PST to plan and teach a series of science lessons to small groups in a school, with class teachers not necessarily involved.	5 +(4 Deakin) +(1 ACU)	(25%)
3	Opportunity for PST to plan and teach a series of science lessons to small groups in a school, prepared in consultation with the class teacher.	3 +(1 Melb) +(1 RMIT)	(12.5%)
4	Opportunity for PSTs and class teacher to collaboratively plan a series of science lessons, and for PST to teach the class and assess student progress.	2 +(1 UTAS)	(7.5%)
NA	University coordinated professional learning support for classroom teachers in schools to teach science (e.g. "My Science")	2	(5%)
	Total	**34(40)**	**100%**

Of the 15 academics who reported no school based component to their science education program, two said they would consider developing a school-based aspect to their program in future. Of those who reported a school-based component in their science education program, two reported on programs that were primarily concerned with teacher professional learning rather than preparing PSTs. As the focus of the STEPS project was pre-service teacher science education, these two have been labelled as Not Applicable (NA) in Table 2 but much of the feedback from these academics was still pertinent to the research. While the possibility for teachers' professional learning through their involvement in these programs has been reported in the literature (Jones, 2008; Kenny, 2009; Murphy et al. 2004), this was not specifically targeted in this data and indications from the research are that it would be more likely in the case of programs operating at scope levels 3 & 4, where the teachers were specifically included as part of the teaching program.

This paper will now explore the experiences of the teacher educators, as described in the interviews in more depth by examining the prevalence of the practices, the theories informing the programs and practice, the key characteristics of the programs (including the role of the teacher educators, and issues around their sustainability.

1. Prevalence

It is significant that 23 (57.5%) of the 40 teacher educators included some form of school-based activities for PSTs in their science education program. In general the programs tend to have been designed, initiated and or organised by a science educator to better meet the needs of their science education students. Several who were not using school-based approaches expressed a desire to do so but felt constrained by resources or the apparent effort needed to establish and maintain the programs. As indicated in Table 2, however, the scope of the school-based activities varies considerably. Clearly the purpose and nature of any school-based components needs to be justifiable, aligned with the desired learning outcomes and may be influenced by local factors and constraints.

2. Theories informing practice

The feedback indicates that every school-based program, irrespective of its scope, was designed to provide an authentic experience for the PSTs by actually teaching science to students. Twelve respondents referred to constructivist, inquiry based learning as their informing theory, usually in the context of 5Es approach (Bybee, 1997). The school-based learning activities were seen as an effective way to help their students make links between the theory and practice of teaching science, and all respondents indicated that reflection on the teaching experience by the PSTs was built into the programs:

> *…PSTS have an authentic experience of teaching science… They are able to observe their peers teaching science which gives them an opportunity to learn about different teaching styles… They receive feed-back from their peers, a class-room teacher (or mentor), and their university educator. (Agnes)*

In terms of other theories under pinning their school-based approaches, 4 respondents mentioned situated learning theory, 4 mentioned socio-cultural learning, 4 referred to theories of self-efficacy and 2 referred to programs which made use of science mentors.

3. The key characteristics of the programs

The school-based science activities reported occurred within a range of teaching programs for both secondary and primary PSTs. Five were in graduate programs including Dip Ed and Masters and 11 were B Ed programs, usually in the 3rd or 4th year after the students had some theoretical background to draw on:

> *{The unit occurs}…Half way through the subject so the students have been introduced to curriculum fundamentals, pedagogy, good principles in science instruction, planning, they've had exposure to a wide variety of pedagogical frameworks. (Allan)*

The student numbers involved tended to vary considerably. Student cohorts of 20 through to 400 were reported, with PSTs often going out into schools in tutorial groups. When teaching students in school, the ratio of PSTs to students in class also varied. In most cases, students worked in pairs with small groups of 2-6 students, but some taught on their own taking a half or whole class. Often this was determined by the availability and the size of the school.

Five universities reported their science education programs included more than one unit. The school-based activities were usually reported as core units (i.e. delivered to the whole PST cohort) and two were described as an elective in fourth year which was preceded by a core science unit (not necessarily school-based) earlier in the program.

The school based activities were timetabled to coincide with the school teaching terms but this did not guarantee teachers could participate. For example, Zanthe noted that during report writing time and periods where when the compulsory National Assessment Program for Literacy and Numeracy (NAPLAN) standardised tests were underway, it was difficult to get teachers to engage. Getting teachers more involved in the school-based science programs, clearly needed some effort on behalf of the science educators:

> *Actually getting the teachers involved can be challenging. Some teachers really get into it and some teachers use the time to get their work which is a bit sad because it's about the teachers getting involved as well. (Lila)*

Harry described a school-based program which is integrated into the normal operations of the school, but developing a program of this scope clearly took a lot of effort by the teacher educator:

> *When our students are doing it, it's not an add-on. There's no smoke and mirrors, it is actually situated in the school's curriculum and the reports that are developed on children's learning are then given back to the teachers. So to me that is authentic, real life and we know the literature around teaching science around early childhood, primary is often about resource management and the like and their understanding of content…(Harry)*

This highlights the potential of these programs to engage the school on a deep level, to deliver tangible mutual benefits for the school and the university and the important role of the teacher educator in building relationships with the school leadership and staff:

> *One of the schools has been there ever since and that's a close school so it's very convenient. We've always had a very relaxed relationship with them. Two of the other schools I was approached by ex-students who wanted their school to be involved. (Ivan)*

Therefore, the notion of good communication underlies many of the specific points raised by the participants. For the university educators, the school setting provides access to a valuable learning environment which cannot be emulated otherwise:

> *…we are gaining something that we benefit from but wouldn't otherwise have which is access to children and also access to the school environment. To the context in which we do the tutorial and the context in which we are is most important. It is the mutuality of it. (Ivan)*

But the ongoing arrangements clearly also have mutual benefits. While the learning potential for PSTs of the school-based science activities was obvious, their potential as professional learning for the teachers was also raised by one academic:

> *…that it is good professional development for the teachers who are involved in the mentoring of the pre-services teachers in the schools. (Matthew)*

The success of these programs relied on a clear understanding of the expectations of all parties and a supportive school leadership:

> *…the schools' community has to be aware these pre-service teachers are [there] and that having and an impact on the children's learning is a good thing. I know the principal and deputy principal have spent a lot of time keeping their community informed of what it means and they keep them informed. (Harry)*

4. Role of the teacher educator

Establishing and maintaining relationships with the schools seems to be very important part of role of the science educator, irrespective of the scope of the program. As the initiators of the school-based programs, they were the main contact with the schools and had to ensure it met the requirements of the university while meeting the needs of the schools and PSTs. The educators often also reported difficulties operating within university constraints. Several educators reported that they were the only science educator, which meant running the program was very demanding on their time. Allan felt this was particularly pertinent for programs which aimed to get the teachers in a school actively involved:

> *The last thing you want is teachers putting up their hands and saying we want you to come, work with our kids but then they don't engage with the process. In other words, it's just perpetuating that problem that there tends to be a low efficacy and maybe a low priority to science… (Allan)*

5. Sustainability and Success

In evaluating their school-based programs, the science teacher educators referred to direct feedback as evidence, but this was largely self-reported data from the teachers, principals and PSTs who participated, usually in the form of interviews, surveys and focus groups. They all reported that their PSTs gained a lot from the school-based teaching activities, which was their main motivation for setting up the school-based programs in the first place:

> *... [the PSTs] loved the experience. They found that they did learn so much about science and it did dispel their fears which they had brought with them. If you're are talking about identity it did change them … the way they saw themselves as science teachers and how to teach science. (Anges)*

The triangulation between these forms of data and the continued enthusiasm of the schools and PSTs served as a means of validation for the school-based approach and provided evidence of benefit to all participants and was consistent with the experience of those in the STEPS project.

A significant indicator of the success her program, for Valerie, was the fact that a school was willing to be involved in future offerings of the program. Barry also saw continued involvement as a clear indicator of success with his program and the fact that the school was prepared to adjust its teaching program to suit the constraints of the university. He also saw potential PD for the teachers that their on-going involvement may offer through modelling good science activities with their students:

> *They're pretty keen to have us there so it's transformative in that way... I'm using this as an opportunity to show [the teachers] that there's some really fun little activities that show some good science and it's easy to use with equipment that is easy to get your hands on. (Barry)*

Clearly some mutual benefit for the school and the university is behind the continuing participation of both parties.

6. Obstacles, blockers and challenges

In an era of reduced funding for higher education, the cost implications of running school-based programs were also mentioned:

> *…it was a pretty expensive model from the university point of view. The school got a lot out of it but because we could only take small groups into school, it made it costly. (Brianne)*

These costs were associated with the need for university staff to travel to be in schools in cases where university tutorials were conducted in school settings or for observational visits. A number of other challenges were outlined. India reasoned that a large cohort of PSTs would be difficult to accommodate in a school-based program and she suggested a fourth year elective as one way of managing this problem, as there would be fewer students involved and that it would also provide a degree of specialisation in science and advantageous for the PSTs in gaining employment.

Matilda explained that university's policy of rapid growth in student numbers, a shift to online learning and organising the program across multiple campuses affected their program. Also, increasing use of sessional staff had made their school-based activities, built up over many years, unsustainable:

> *We went across…five campuses and on-line as well so it's become incredibly complicated… you have an awful amount of sessional staff…I would have been the only permanent staff working…so the rationale was to make sure it was on-line, be flexible and to be big… It's about economics of scale…we would keep saying how's this going to work for the students and we'd be told don't worry about… (Matilda)*

Academics from two other universities also felt that that increasing use of distance or online learning was a significant challenges to their school-based science teaching activities:

> *We've finally got permission to go to the other campuses next year but our courses have been restructured. The first unit of Science and Technology they want to do externally [i.e. online] so that's going to make it very difficult. Not quite sure how we will go about it. (Lila)*

Some science educators also mentioned a range of logistical problems associated with working off-campus including: the need for transport, of both PSTs and science equipment, as well as parking at the school location. Additionally, the school needs to be close by for PSTs who have to return to the university to attend other classes. There were cases where students have also had to purchase materials to use in their classes. While these problems can be minimised through careful planning, negotiation of the times in class, car-pooling, awareness of resources available at the university and in the schools, they place extra demands on the teacher educator coordinating the programs which may escalate if they have also to undertake visits to the schools to observe PSTs. There is no doubt that establishing and maintaining the school-based programs places significant demands on the academics coordinating the programs:

> *I've realised working with primary schools, you need to work in quite long term forward planning In this particular year, from a view of the university establishing partnerships, I think it's become apparent that these things don't happen overnight. You have to take the time to build the relationships and get to know when the planning meetings are on… (Andrew)*

Allan raised questions about the supervisory requirements when his PSTs work in schools and the increasing number of PSTs studying off-campus, as problems, but pointed-out that the school-based component is so popular with PSTs that he wants to find a solution:

> *…our students want to engage in schools and have field based experiences. Our schools want us to engage with them. It might be next year we have students come on campus rather than we have to go to the field to try to work with them… (Allan)*

At the moment, many of these programs rely on the good will of the science educators and the tutors, which raises questions about their sustainability:

> *The funding allowed for tutors is limited and the school-based program demands more time commitment by the tutors who have to liaise with the school, collect equipment and transport it to the school, and they are generally not paid extra for the time that this takes. This year, some extra salary was negotiated at [Campus] in recognition of this extra effort. (Ivan)*

Other teacher educators pointed to the increasing difficulty of getting access to schools due to demands placed them for the practicum placements. While in most examples presented the school-based science education programs were operating outside of the normal practicum, this is an issue for consideration.

> *Our research findings have shown that the school-based approach enhances our students' confidence to teach science and technology and their ability to connect theory with practice. There has been a noticeable difference in the unit satisfaction … from the campus where the school-based approach is presented compared with the unit satisfaction from the student where it is a university based approach. (Lila)*

Given the powerful learning experiences reported, could science teaching be a 'win-win' for schools and universities? For example, could PSTs in school-based science teaching situations gain credit against the teaching standards (AITSL, 2014)? Are these programs adequately resourced? Does the potential PL for the mentor teachers make school-based science programs a cost effective way of developing their teachers and raising student performance?

CONCLUSIONS

In the context of criticism about the quality of university teacher education generally and particular problems associated with science education as highlighted in current discussions about STEM subjects, and their importance for national economic development, this paper explored the prevalence of school-based teaching approaches in science education programs in Australia. While all university teacher education courses must include practical teaching components, universities tend to have little control over the quality of mentoring received in the practicum or, for primary PSTs, whether they get to teach science at all.

Dedicated school-based science teaching experiences, with support from the university science teacher educators, have been shown to build the confidence of primary PSTs to teach science (Kenny 2010). Some science educators also mentioned a range of logistical problems associated with working off-campus including: the need for transport, of both PSTs and science equipment, as well as parking at the school location. Additionally, the school needs to be nearby for PSTs who have to return to the university to attend other classes. Cases were reported where students had to purchase materials to use in their classes. While these problems can be minimised through careful planning, negotiation of the times in class, car-pooling, awareness of resources available at the university and in the schools, they place demands on the teacher educator coordinating the programs, which may escalate if they are required to undertake observational visits to the schools. There is no doubt that establishing and maintaining the school-based programs places significant demands on the academics coordinating the programs:

> *I've realised working with primary schools, you need to work in quite long term forward planning In this particular year, from a view of the university establishing partnerships, I think it's become apparent that these things don't happen overnight. You have to take the time to build the relationships and get to know when the planning meetings are on… (Andrew)*

The forty science teachers, representing two-thirds of university science education programs, presents an idea of the extent of school-based science education in Australia. Over half of the science teacher educators in this study have some sort of school-based science teaching experience for their PSTS, however the scope of the school-based teaching component was found to vary greatly between the universities, often due to local constraints.

The role of the teacher educators in initiating, organising and maintaining these programs is crucial. Where they occurred, the science teacher-educator was usually the initiator, chief organiser and/or co-ordinator of the interactions with their schools. As the scope of the school-based programs becomes more integrated with the schools' programs, their role becomes more complex, in terms of negotiating the interactions and clarifying the expectations. Some teacher educators who do not use school-based approaches expressed a desired to do so, but often the perceived organisational difficulties and extra workload demands held them back. Other factors mentioned for avoiding school-based approaches included the rise in online (or off-campus) learning, dealing with large student cohorts and perceived difficulties associated with an overlap with the practicum.

In Australia, school-based approaches are valued by the majority of science teacher educators because of the authenticity of the learning opportunities they present for PSTs to link theory and practice. As the approach is in-line with recent calls for greater cooperation between universities and schools to improve teacher education (TEMAG, 2014), they may present an important option when re-thinking university based teacher education, so it would be important to research the extent to which such school-based options are being considered internationally within science education and teacher education more generally.

The paper has raised a number of questions for further research including:

1. To what extent are school-based PST science programs used internationally and why?
2. Do school-based approaches work effectively curriculum areas other than science, e.g. Arts?
3. Does involvement in school-based programs lead to improved teacher performance in science and better learning outcomes for students?
4. Can teacher education programs which incorporate school-based programs be designed to suit PSTs studying off-campus?
5. How school-based approaches to science education impact on, or can be integrated with, the traditional school practicum?

6. How do the resource demands and effectiveness of school-based science programs compare with non-school-based programs?
7. Are school-based programs a cost-effectiveness form of professional learning for teachers?

REFERENCES

Akerson, V.L. (2005). How do Elementary Teachers Compensate for Incomplete Science Content Knowledge? *Research in Science Education*. 35(2-3): 245-268.

Alake-Tuenter , Harm J.A. Biemans, Hilde Tobi, Arjen E.J. Wals, Ida Oosterheert & Martin Mulder (2012): Inquiry-Based Science Education Competencies of Primary School Teachers: A literature study and critical review of the American National Science Education Standards, *International Journal of Science Education*, 34(17), 2609-2640. http://dx.doi.org/10.1080/09500693.2012.669076

Australian Council of Deans of Education (ACDE) (2004), Submission to the Victorian Parliamentary Inquiry into the suitability of pre-service teacher training in Victoria.

Bybee, R. W. (1997). *Achieving scientific literacy: From purposes to practices.* Portsmouth: Heinemann.

Darling-Hammond, L. (2000). Teaching quality and student achievement: A review of state policy evidence. *Education Policy Analysis Archives*, *8*(1).

Darling-Hammond, L. (2006). Constructing 21st century teacher education. *Journal of Teacher Education*, *57*(3): 300-314.

Dobson, I. (2003). *Science at the crossroads? A study of trends in university science from Dawkins to now 1989-2002*, Centre for Population and Urban Research, Monash University. A study commissioned by the Australian Council of Deans of Science.

DEEWR (2003), *Australia's Teachers: Australia's Future Advancing Innovation, Science, Technology and Mathematics*. Committee for the Review of Teaching and Teacher Education, Canberra: Commonwealth of Australia. [Retrieved, May 2009 from: http://www.dest.gov.au/sectors/school_education/policy_initiatives_reviews/reviews/teaching_teacher_education/review_of_teaching_and_teacher_education_home.htm]

(DEST) (2003). *Australia's teachers: Australia's future - advancing innovation, science, technology and mathematics*. Canberra, ACT, Australian Government Department of Education, Science and Training: 7.

Hackling, M. (2006). *Boosting science learning: What will it take?* Retrieved March 26, 2010, from http://research.acer.edu.au

Hobbs, L. (2013). Teaching 'out-of-field' as a boundary-crossing event: Factors shaping teacher identity. International Journal of Science and Mathematics Education, 11(2), 271-297.

Hobbs, L., Jones, M., King, J., Chittleborough, G., Redman, C., Campbell, C., Kenny, J., Herbert , S. (2013). *Science Teacher Educator Partnerships with Schools (STEPS): Developing an Interpretive Framework for Primary Science Teacher Education*. Presented to the Contemporary Approaches to Research Symposium, 2013, Deakin University. http://www.deakin.edu.au/__data/assets/pdf_file/0007/367036/paper4.pdf

Hobbs, L., Campbell, C., Chittleborough, G., Herbert, S., Jones, M., Redman, C., Kenny, J., Gilbert, A., & King, J. (2015). *Interpretive Framework*. The Science Teacher Education Partnerships with Schools (STEPS) Project. *Project website:* http://www.stepsproject.org.au

Hobbs and Törner (Eds.) (2014). *Taking on International Perspective on "Out-of-Field" Teaching: Proceedings and Agenda for Research and Action from the 1st Teaching Across*

Specialisations (TAS) Collective Symposium. TAS Collective. Available from: https://www.uni-due.de/TAS
Howitt, C. (2007). Pre-Service Elementary Teachers' Perceptions of Factors in an Holistic Methods Course Influencing their Confidence in Teaching Science. *Research in Science Education*, *37*(1), 41-58.
Jones, M.M. (2008). Collaborative partnerships: A model for science teacher education and professional development. *Australian Journal of Teacher Education*, *33*(3), 61-76.
Kenny, J. (2009). Pre-service and in-service teachers working together teach primary science. *Australian Journal of Teacher Education*. 34 (6), 1-22.
Kenny, J. (2010). 'Preparing primary teachers to teach primary science: a partnership based approach.' *International Journal of Science Education*, 32 (10), 1267-1288.Kenny, John Daniel (2012) "University-school partnerships: pre-service and in-service teachers working together to teach primary science", *Australian Journal of Teacher Education*: 37 (3/6). Available at: http://ro.ecu.edu.au/ajte/vol37/iss3/6
Kenny, J., Hobbs, L., Jones, M., Chittleborough, G., Campbell, C., Gilbert, A., Redman, C., and Herbert, S. (2014). Science Teacher Partnerships with Schools (STEPS): Project-Partnerships in science teacher education. *Australian Journal of Teacher Education*, 39(12), 43-65.
Kenny, J. and Hobbs, L. (2015). *Researching with in-service teachers teaching 'out of field'.* Presented to the Contemporary Approaches to Research Symposium, 2015, Deakin University. Available online from https://www.deakin.edu.au/research/crefi/events-and-conferences/car-symposia (awaiting publication).
Kenny, J., Redman, C., Hobbs, L., Jones, M., Campbell, C., Gilbert, A., Chittleborough, G. and Herbert, S. (2014), *Developing effective school and university partnerships for teacher education*. In Proceedings of 6th Annual EduLearn Conference on Education and New Technologies, 7th-9th July, 2014, Barcelona, Spain. ISBN: 978-84-617-0557-3.
Keys, P. (2005). Are teachers walking the walk or just talking the talk in science education? *Teachers and Teaching: Theory and practice, 11*(5), 499-516.
Korthagen, F. (2001). *Teacher education: a problematic enterprise in linking practice and theory: the pedagogy of realistic teacher education*. Mahwah, N.J., Lawrence Erlbaum Associates Inc.
McCaleb, J., Borko, H., & Arends, R. (1992). Reflection, research and repertoire in the masters certification program at the University of Maryland. In L. Valli (Ed.) *Reflection in teacher education*, pp.40-64. Albany: State University of New York Press.
Murphy, C., Beggs, J. Carlisle, K., & Greenwood, J. (2004). Students as 'catalysts' in the classroom: The impact of co-teaching between science student teachers and primary classroom teachers on children's enjoyment and learning of science. *International Journal of Science Education*, *26*(8), 1023-1035.
Office of the Chief Scientist. (2014). Science, Technology, Engineering and Mathematics: Australia's Future. Australian Government, Canberra.
Srikanthan, G., & Dalrymple, J. F. (2002). Developing a holistic model for quality in higher education. *Quality in Higher Education, 8*(3): 215-224.
TEMAG (2014). *Action Now: Classroom Ready Teachers.* Report of the Teacher Education Ministerial Advisory Group. Accessible online at https://docs.education.gov.au/node/36783
Tytler, R. (2007). *Re-imagining science education: Engaging students in science for Australia's future*. Australian Council for Educational Research. Melbourne: ACER.
Tytler, R., Osbourne, J., Williams, G., Tytler, K., and Cripps Clark, J. (2008) *Opening up pathways: Engagements in STEM across the Primary-Secondary school transition*. Canberra: DEEWR.

EMPOWERING STEM TEACHERS: DEVELOPMENT OF A MULTIDISCIPLINARY PEDAGOGICAL STEM COURSE

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Abstract: Many studies show that only a small number of secondary school students choose STEM (Science Technology Engineering Mathematics) related studies after high school. One of the indicated reasons is that STEM in secondary school is divided in the different disciplines and taught as such. In order to accomplish motivating and challenging STEM education in which pupils acknowledge the relevance and the interaction amongst the disciplines, an integrated STEM approach is crucial. In this research project we aim to develop such a multidisciplinary pedagogical STEM course for pre-service STEM teachers. In a preliminary study we investigated the view of STEM educators on the current and ideal teaching of STEM courses. The results clearly show that for all disciplines the current approach focuses on specific discipline knowledge and algorithmic problem solving. All experts indicate the need of a transfer to a more multidisciplinary STEM approach which focuses on developing problem solving techniques, conceptual thinking, linking different STEM disciplines and context rich learning environments. The main goal of the multidisciplinary pedagogical STEM course is to strengthen the PCK of pre-service teachers (specialized in a specific STEM discipline) in order to accomplish an optimal implementation of the multidisciplinary STEM aspects.

Keywords: STEM, pre-service teachers, pedagogical course, multidisciplinarity

INTRODUCTION

A significant proportion of secondary school students experience mathematics and science as abstract and theoretical with little applicability to daily life (Freeman e.a.,2014). Due to the rather strict division within similar STEM related disciplines, students develop little or no experience in solving interdisciplinary or multidisciplinary scientific problems, and as a result, they fail to grasp the relevance of STEM classes (Van Houte et al., 2013). As indicated in the ROSE-project (Sjøberg and Schreiner, 2010), only a small number of secondary school students tend to choose STEM related studies after high school. In response to the increasing demand for STEM graduates, the Flemish government developed the ‘STEM Actie Plan’ (STEM Action Plan) in 2013 (Flemish Government, 2012). Since then, a significant number of secondary schools have taken the initiative to offer specific STEM related studies.

An integrated STEM approach is crucial in order to successfully achieve a motivational and challenging STEM education in which pupls understand the relevance and interaction amongst the different STEM disciplines and learn to tackle multidisciplinary problems (Bransford et al, 1999; Tan et al., 2012;Van Houte et al., 2013; European Schoolnet Academy, 2014). This approach should be used to prepare pre-service teachers both to develop and manage specific STEM projects in a context where learning is based on problems, projects and designs and to teach the separate STEM disciplines where interaction amongst the various STEM disciplines is clear.

In the Netherlands, scientists, teachers and teacher trainers have been actively addressing the same issue for several years. There, innovation concerning STEM (education) is channelled into the Platform Bèta Techniek (Science and Technology Platform). Partly as a result of the implementation of this new didactical approach, the inflow of pupils into STEM related studies in the Netherlands has increased by 15% in three years (YoungWorks, 2011).

In this project, we wanted to build on these developments and focus more specifically on the education of (pre-service) teachers in the STEM field, who after all must be prepared to fulfil their educational tasks in a constantly evolving context.

To achieve such competence, (pre-service) teachers require a strong pedagogical content knowledge (PCK). Since its introduction in 1986 by Shulman, many researchers have acknowledged the importance of PCK for teaching, lesson plan preparations and teacher professional development (Cochran,1997; Hume, 2010; Loughran, 2012).

This project reports on the development of a multidisciplinary pedagogical STEM course to improve the quality of PCK in pre-service STEM teachers in an interdisciplinary and multidisciplinary approach of teaching.

METHODS

To define the goals of the multidisciplinary pedagogical STEM course, a survey was designed to gain insight into:

- the crucial characteristics of powerful STEM teachers;
- the current and the ideal approach to STEM subjects; and
- the need for and possibilities of a pedagogical course with an integrated STEM approach.

The survey was conducted in Flanders; respondents included both experts (20 experienced mathematics/science teachers and teacher trainers) and pre-service STEM teachers (53 pre-service secondary school teachers in a STEM discipline).

Based on these results and a literature review, a pedagogical course was developed in order to prepare pre-service teachers as powerful STEM teachers.

RESULTS

1. *Crucial STEM teacher qualities*

As an introductory question, participants were asked to list the four crucial STEM teacher qualities, drawn from their own view and experiences. The results are shown in Figure 1. The variety of answers, both for experts (left word cloud) and pre-service teachers (right word cloud) is high. Within this variety however, the focus of the two groups is different. All participants recognize the importance of content knowledge but the two groups differ in their views on other characteristics. The experts prioritise STEM specific qualities such as multidisciplinary thinking and inquiry-based learning, while pre-service teachers enumerate more general pedagogical qualities.

Pre-service teachers Experts

Figure 1 Crucial STEM teacher qualities, as given by both pre-service teachers and experts

2. *Presence of STEM specific aspects in secondary school education*

Based on the literature (Bransford et al, 1999; Youngworks, 2011; European Schoolnet Academy, 2014), nine specific STEM aspects were selected of which the meaning was explained in the survey:

- Specific Discipline Knowledge: focus on managing specific content knowledge
- Algorithmic Problem Solving: exercises, problems, assignments, ... to be solved according to a proposed grid
- Designing Problem Solving Techniques: pupils must design their own method to deal with an exercise, question, assignment, et cetera
- Active learning: learning by doing, the thinking process is put in motion when working on exercises, lab practical sessions, and conceptual questions
- Context-rich learning environment: both the description and practice of new concepts is done with realistic problems and examples
- Conceptual understanding: focus on understanding the meaning of concepts or formulas rather than the formulas or formulation of the concepts
- Motivating approach: pupils are very involved and challenged; this must go beyond arousing interest to the extent that pupils find the course 'fun'
- Multidisciplinary approach: links are being made to the other STEM disciplines in examples and applications. This does not mean that each STEM discipline needs to be taught in the same way.
- Attention for possible future as a STEM professional: STEM classes provide an overview of the variety of professional contexts in which people STEM professionals can work.

The participants were asked to define to what extent these specific STEM aspects are present in the current and ideal STEM education approaches. The responses vary between 1 (not present) to 4 (strongly present). The mean of the responses was calculated and is presented in Figure 2.

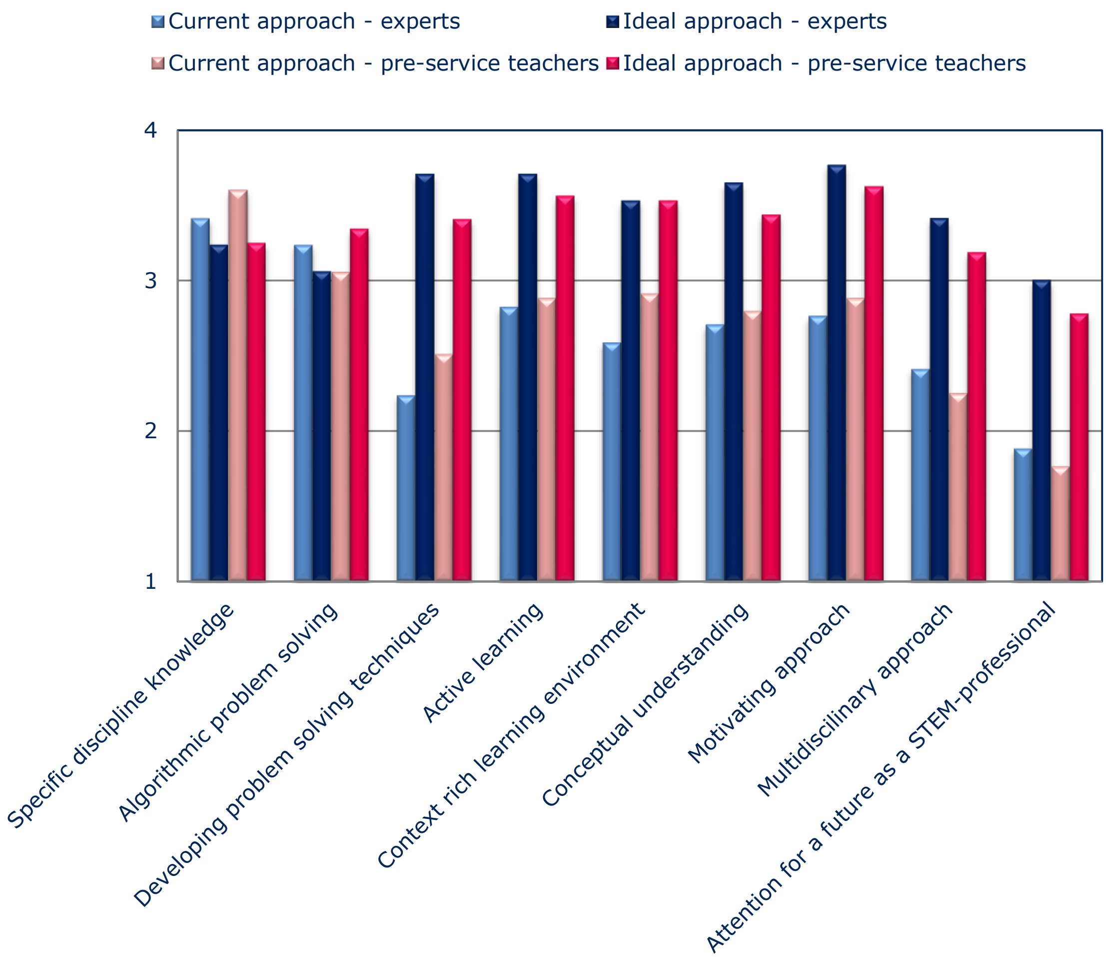

Figure 2 Presence of specific STEM aspects in secondary schools: mean of responses (1:not present to 4:strongly present).

Generally, the responses of the experts (blue bars) are similar to the responses of the pre-service teachers (red bars). Differences in the STEM discipline specialisation of the respondents did not result in measurable differences in their responses (data not included). The highest scores (≥3) in the current approach were measured for Specific Discipline Knowledge and Algorithmic Problem Solving; differences in other specific STEM aspects are less present (score <3).

According to both the experts and the pre-service teachers, the ideal approach requires a strong presence of the following more neglected aspects:

- The aspects 'Designing Problem Solving Techniques', 'Active learning', 'Context Rich Learning Environment, 'Conceptual Understanding', 'Motivating Approach' and 'Multidisciplinary Approach' score higher than 3 for the ideal approach;
- The score for 'Attention for Possible Future as a STEM Professional' has doubled from the current to the ideal approach.

Next to the high degree of similarity in the responses between the experts and the pre-service teachers, two important differences are noted. Firstly, the experts feel a greater need for a different/new approach (greater differences between current and ideal approach). Secondly, the experts clearly support a greater focus on designing problem-solving techniques, while pre-service teachers believe that algorithmic problem solving and the design of problem-solving techniques are equally important.

3. *Necessity and possibilities of a multidisciplinary STEM course for pre-service teachers*

To determine the necessity and possibilities of a pedagogical STEM course that aims to increase the PCK of pre-service teachers to become competent STEM teachers, the participants were asked their opinion on a number of statements. The responses vary between ‘strongly disagree’ (1) and ‘strongly agree’ (4) and the mean value of the responses is calculated and plotted in Figure 3.

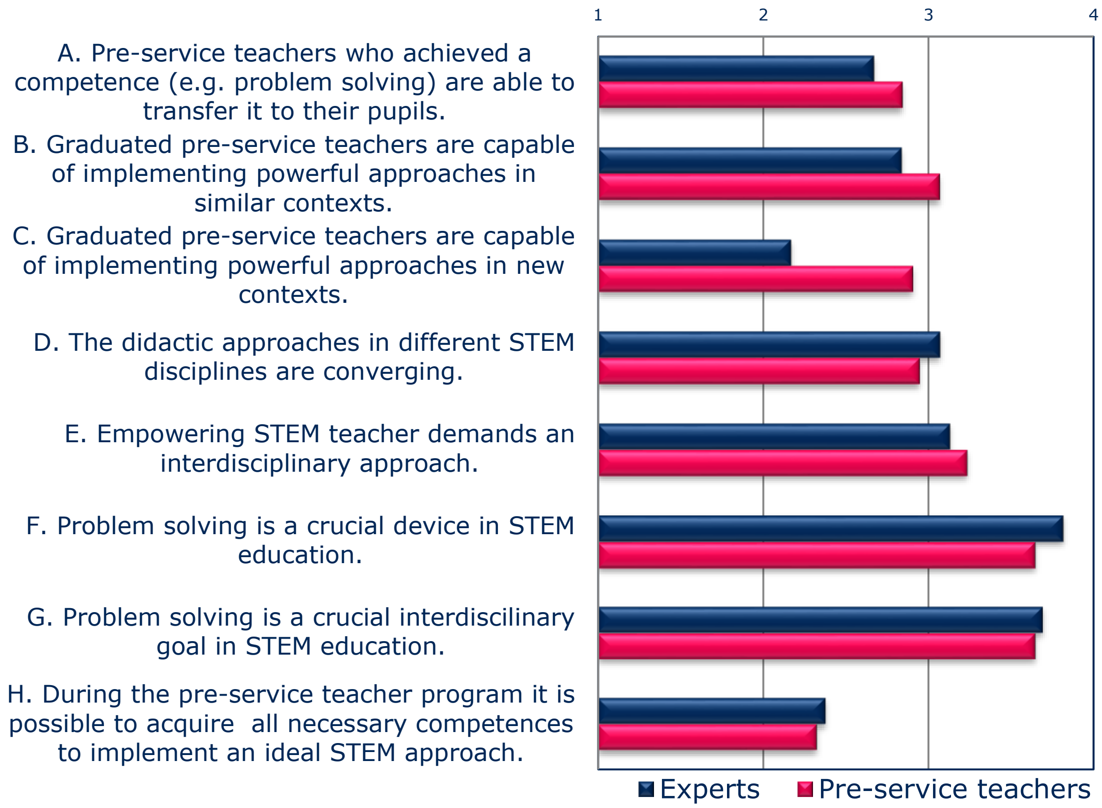

Figure 3 Necessity and possibilities of a multidisciplinary STEM course for pre-service teachers: mean of responses (1:strongly disagree to 4:strongly agree).

In general, the experts’ responses (blue bars) are again similar to the responses of the pre-service teachers (red bars). Statements A, B and C score below three: the participants indicate that the achievement of a specific competence (e.g. problem solving) or the study of best practices by pre-service teachers do not necessarily mean that these skills can be used by the pre-service teachers in a variety of contexts. The pre-service teachers were more likely than the experts to demonstrate their belief in their own ability to deploy strong STEM educational approaches in new and unfamiliar contexts (score ca. 3 versus ca 2 for statement C).

On the one hand, the high scores for statements D, E, F and G (> 3) indicate that the implementation of a multidisciplinary approach with problem solving as its central theme offers additional possibilities. On the other hand, the relatively low rating of statement H points out the limitations of a STEM pedagogical course for pre-service teachers.

DISCUSSION

General implications

From the survey, three trends become clear. First, pre-service teachers find it difficult to enumerate crucial STEM teacher qualities based on the knowledge and skills learned in the separate discipline-related pedagogical courses. They do not distinguish the STEM teacher profile from the general teacher profile. Second, both experts and pre-service teachers believe there is a difference between the current approach and ideal approach in high school STEM education. This implies that a shift is needed from specific discipline knowledge and algorithmic problem solving to designing problem-solving techniques, active learning, a context-rich learning environment, conceptual understanding, and a motivational and multidisciplinary approach. It should be noted that pre-service teachers do not distinguish adequately between algorithmic problem solving and designing problem solving techniques. The pre-service teachers therefore pursue an increased focus on both in the ideal approach. Finally, both experts and pre-service teachers acknowledge the added value of a multidisciplinary pedagogical STEM course that could offer a foundation for the implementation of a strong learning environment in a variety of contexts.

Development of a multidisciplinary pedagogical STEM course

a. Goals of the pedagogical STEM course

The results indicate that to optimally train pre-service teachers to become powerful STEM teachers, a STEM pedagogical course must aim to achieve these goals :

GOAL 1 Pre-service teachers can distinguish the STEM teacher profile of the general teacher profile

GOAL 2 Pre-service teachers are aware of the shortcomings of the current approach in STEM education

GOAL 3 Pre-service teachers get to know and recognize the characteristics of good practices for multidisciplinary STEM education where "inquiry based learning" is central

GOAL 4 Pre-service teachers are able to implement relevant STEM aspects in a variety of contexts

b. Modules of the pedagogical STEM course

The pedagogical STEM course exists out of six modules. Each of these modules works around one or more central goals. To emphasize the value of goals three and four, several modules work around these goals. An overview of the modules can be found in Table 1.

	Objective	Activities
Module 1	GOAL 1 Pre-service teachers can distinguish between the STEM teacher profile and the general teacher profile	• Complete survey • Confrontation with and discussion about survey results • Background information on STEM education in Flanders with lesson observation in STEM school
Module 2	GOAL 2 Pre-service teachers are aware of the shortcomings of the current approach in STEM education	Exploration of the specific STEM aspects in lesson plans and modules, including introducing students to: • shortcomings of the current approach based on lesson plans developed by pre-service teacher • the ideal approach based on existing multidisciplinary modules developed by interdisciplinary teams • the current approach based on lesson observations during internship teaching
Module 3	GOAL 3 Pre-service teachers recognize the characteristics of best practices for multidisciplinary STEM education where “inquiry based learning” is central.	• Discussion of the specific STEM aspects in examined multidisciplinary modules • Assignment about solving multidisciplinary problems, involving instruction about the difference between: - a problem and an exercise - provision of a solution method and the stimulation to design a solution method based on sample problems and a metacognitive questionnaire
Module 4	GOAL 3 Pre-service teachers recognize the characteristics of best practices for multidisciplinary STEM education where “inquiry based learning” is central	• From confrontation to motivating lesson (plans): - approach with existing syllabi - approach with personally developed materials • Analysis of the application of specific STEM aspects during multidisciplinary problem solving
Module 5	GOAL 3 Pre-service teachers recognize the characteristics of best practices for multidisciplinary STEM education where “inquiry based learning” is central GOAL 4 Pre-service teachers demonstrate ability to implement relevant STEM aspects in a variety of contexts	• Blended literature assignment based on relevant articles with met supporting focus questions concerning: ✓ new insights in pedagogical approaches ✓ recognize implementation possibilities in own teaching practice • Exchange of insights and concrete translation to own teaching practice: ✓ what have you learnt from the pedagogical course? ✓ how can you realize a sustainable implementation in own teaching practice?
Module 6	GOAL 4 Pre-service teachers are able to implement relevant STEM aspects in a variety of contexts	• processing of gained insights in teaching practice: ✓ individual lessons during internship ✓ series of lessons developed by an interdisciplinary team in the context of a thesis project • Supervision and coaching session

Table 1 The different modules of the multidisciplinary STEM course

c. Implementation of the pedagogical STEM course in the teacher training program

The competences pursued within the pedagogical STEM course are situated in an integration and expert level within the competence matrix of the bachelor secondary school teacher at UCLL Leuven (Unpublished competence matrix). Therefore, the pedagogical STEM course is offered in the third and last year of the teacher training program. The assignments associated with the activities are carried out individually or in interdisciplinary teams. The realization of goal four (pre-service teachers are able to implement relevant STEM aspects in a variety of contexts) occurs primarily in the Bachelor thesis (internship and thesis research). The first five modules are completed during the first two months of the first semester, the sixth implementation module runs during the rest of the third year.

CONCLUSIONS

To motivate students in secondary school to choose a STEM related course of study, it is essential that teachers have specific STEM teaching expertise. A pedagogical STEM course for pre-service teachers to strengthen their PCK in this field was developed.
Based on a survey of experts and pre-service teachers, the necessities and possibilities of the pedagogical STEM course were determined. The results indicated that a shift is needed from the current teacher-led approach, which centralises discipline-specific knowledge and algorithmic problem solving; to a student-driven approach, which puts a priority on problem solving, conceptual understanding and active learning. Both groups of respondents indicated the possibility of a multidisciplinary pedagogical STEM course as the foundation for implementing the specific STEM pedagogy in a variety of contexts.

After processing the results of the survey and a performing a literature review, the authors determined four goals, along the structure and activities of the pedagogical STEM course. We opted for a modular pedagogical course that consists of six modules for which activities were developed to achieve one or more main goals. The sixth (implementing) module was linked to the bachelor thesis.

To be able to achieve a sustainable strengthening of STEM pedagogical expertise in the future, it is important that enough time be provided within the teacher training programme to guide pre-service teachers in the interdisciplinary and multidisciplinary teaching of related subjects throughout the course of the training programme.

REFERENCES

Bachelor Secundair onderwijs KHLeuven (2011). *Opleidingsvisie, opleidingsmodel en competentiematrix van de professionele Bachelor Secundair onderwijs.* KHLeuven, unpublished.

Bransford, John D., Brown, Ann L., & Rodney R. Cocking (1999). *How People Learn Brain, Mind, Experience, and School*. Washington, D.C.: National Academy Press.

Cochran, Kathryn F. (1997). *Pedagogical Content Knowledge: Teachers' Integration of Subject Matter, Pedagogy, Students, and Learning Environments.* Research Matters - to the Science Teacher (9702) Retrieved January 15,2016, from https://www.narst.org/publications/research/pck.cfm

European Schoolnet Academy, *Innovative Practices for Engaging STEM Teaching*, 18th August – 12th October 2014) retrieved January 15, 2016, from http://www.europeanschoolnetacademy.eu/web/innovative-practices-for-engaging-stem-teaching

Flemish Government (2012) *Actieplan voor het stimuleren van loopbanen in wiskunde, exacte wetenschappen en techniek*. Retrieved January 15, 2016, from http://www.stemopschool.be/stem-actieplan

Freeman, S., Eddy, S. L., McDonough, M., K., S. M., Okoroafor, N., Jordt, H., & Wenderoth, M. P. (2014). Active learning increases student performance in science, engineering, and mathematics. *PNAS 111(23)*, 8410-8415.

Hume, Anne (2010). A pedagogical tool for science teacher education: Content Representation (CoRe) design. *Science Teacher Education 59*, 29-38.

Loughran, J., Berry,A., & Mulhall, P. (2012).*Understanding and developing science teachers' pedagogical content knowledge (2th).* Rotterdam: Sense Publishers.

SjØberg , S. , & Schreiner, C. (2010). *The Rose Report. An overview and key findings*. Oslo.

Shulman, Lee S. (1986). Those Who Understand: Knowledge Growth in Teaching. *Educational Researcher*, *15(2)*, 4-14

Tan, Kim C.D., & Kim, Mijung (2012). *Issues and Challenges in Science Education Research*, *Moving Forward*. London: Springer.

Van Houte, H., Merckx, B., De Lange, J., & De Bruyker, M. (2013). *Zin in wetenschappen, wiskunde en techniek. Leerlingen motiveren voor STEM*. Leuven: Acco.

YoungWorks (2011). *Motivaction & Platform Bètatechniek, Bètamentality 2011-2016*. *Jongeren boeien voor Bèta en Techniek*. Rotterdam.

SCIENCE LESSON STUDY ACTIVITY IN A PRE-SERVICE TEACHER TRAINING COURSE

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Abstract: In this paper, we describe the results of our second trial to test a novel approach to lesson activities, supported by a web-based educational-assistance system, for primary school science teachers. We tested this approach in an undergraduate level teacher-training course at the University of Miyazaki, Japan, and present the effects of this approach on students' perspectives on science lessons. After every trial lesson, students input questionnaire responses and comments on the lesson using their own mobile phone or computer; results were displayed on a big screen in the classroom and on each student's mobile. The class then discussed the science lesson with reference to these results. Next, we administered a second questionnaire that required students to write their opinions regarding science lessons before and after a series of trial lessons. Through this series of lessons, we intended to broaden the students' perspectives on science lessons. According to students' written feedback after the trial lessons, they became more conscious of the following important aspects of science lessons for schoolchildren: 'experiment', 'safety', 'motivation', 'observation', and 'explanation'. By contrast, students became less conscious of the importance of the concepts of 'around us' and 'understanding'. At the beginning of lessons, students had a tendency to attach more importance to learner understanding of familiar events and phenomena than of investigating and explaining scientifically interesting events and phenomena. However, after our series of lessons, students tended to attach importance to scientific inquiry (e.g. identifying scientific questions and explaining phenomena scientifically). Therefore, we report that our experimental approach is effective for teacher training because it helps student teachers to develop scientific perspectives on science education.

Keywords: perspectives on science lessons, lesson study, pre-service teacher training

INTRODUCTION

In the first report of our study, which tests an approach to lesson study activity supported by a web-based educational-assistance system (Nakayama & Yamamoto, 2013), we found that throughout a series of lessons, students' perspectives on many points regarding how children learn changed to, for example, 'Children change their own ideas', 'Children become aware of their own ideas', 'Children explain natural events and phenomena in words', and 'Children persuade other children who hold different ideas'. Before the series of lesson study activities, most students attached less importance to such points, but after the activities they became more conscious of them. We therefore find that this approach is effective for teacher training, helping student teachers to develop metacognitive views of science education.

We here present the second report of that study. Both studies were conducted at the University of Miyazaki, Japan. As educators of future primary-school teachers (hereafter, students), we try to help our students to develop constructive views (Duit, 1985; Driver et al., 1985) of their science lessons. In our previous research, we encouraged students to attach more importance to fostering conceptual change in primary-school-age learners; this change is gradually taking hold among the students. However, after a series of lessons in this study, 30% of students still attach less importance to the idea that 'Children persuade other children who hold different ideas' and approximately 10% of students attach less importance to the ideas that 'Children learn about nature by exploring it themselves', 'Children become better able to express their ideas through drawings or spoken or written words', 'Children explain natural events or phenomena using words', and 'Children find the answers to their own questions'. We believe that there is less consciousness among students of the importance of self-directed scientific inquiry and the verbal features of science. Throughout the 2013–2014 school year, we tried to expand students' perspectives on science lessons.

To address this issue, we made the process of trial science lessons more enquiry based. For example, we asked students to make the question for enquiry more concrete for fair testing, to spend sufficient time discussing the record of observation or experiment, and to create occasions for children to explain every phenomenon using scientific knowledge learned during each science lesson. In addition, we introduced a web-based educational assistance system called the Realtime Evaluation Assistance System (REAS) in the trial lessons conducted in our class. Figure 1 shows the sequense of trial science lesson. After every trial lesson, we administered a web-based questionnaire which collected written answers to questions about science lessons, presented the results to the class, and then discussed these results. This approach to lesson study allowed us to focus the class on the attitudes that we intended to help the students adopt. In this paper, we present the effects of the trial science lesson by students and the educational-assistance system on the attitudes of the students in our cohort.

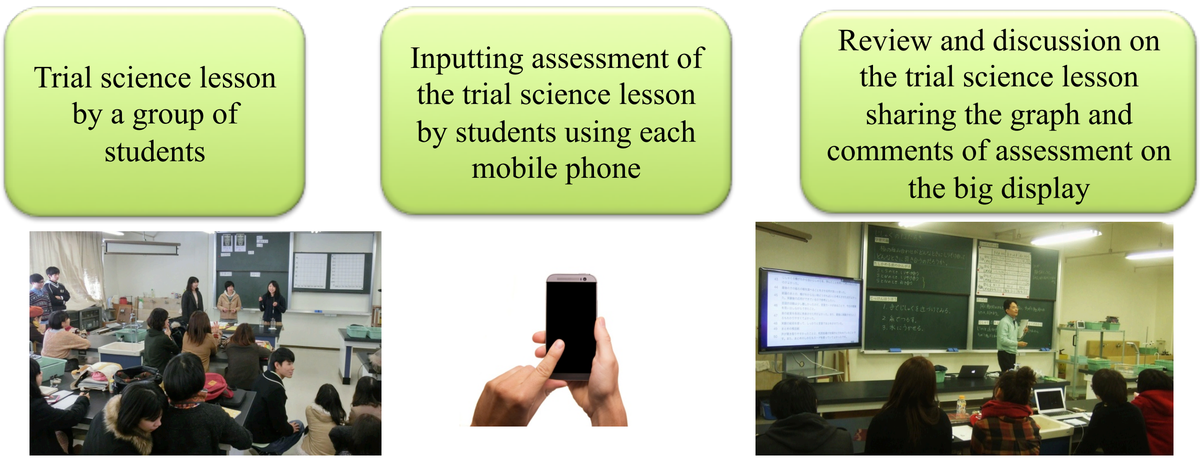

Figure 1. The sequense of trial science lesson.

METHOD

Participants

A total of 56 third-year undergraduate students taking a course called 'Elementary School Science Education' in the latter semester of 2013 participated in our study. Pre- and post-responses from these students regarding their perspectives on science lessons were gathered as data.

Lesson and Questionnaire Design

The schedule is shown in Table 1.

Table 1

Schedule of Lessons

1	Questionnaire on views of science lessons (pre-); lecture: problem-solving activity in science lesson and what is 'problem'
2	(Lecture:) Problem-solving activity in science lesson, the nature of scientific 'problems' and 'questions', and setting a problem and drawing a conclusion
3	Various naïve conceptions in science and how to set a scientific problem
4	Science lesson as a process of children's conceptual change
5	Studying teaching materials and arranging a teaching plan 1 (in groups)
6	Studying teaching materials and arranging a teaching plan 2 (in groups)
7	Studying teaching materials and arranging a teaching plan 3 (in groups)
8	Trial science lesson 1: The character of magnets (third-grade science)
9	Trial science lesson 2: The function of wind and gum (third-grade science)
10	Lecture by a primary school teacher: Actual primary school science lessons
11	Trial science lesson 3: The nature of bubbles in boiling water (fourth-grade science)
12	Trial science lesson 4: The weight of salt dissolved in water (fifth-grade science)
13	Trial science lesson 5: Why the moon waxes and wanes (sixth-grade science)
14	Questionnaire on views of science lessons (post-); lecture: what is science lesson?

Each trial-lesson class session consisted of the following components:

A) The first half of a trial science lesson conducted by a group of student teachers (15 minutes)

B) Experiment by students acting as schoolchildren, guided by the student teachers (15 minutes)

C) The latter part of the trial science lesson by another group of student teachers (15 minutes)

Each trial lesson should include the activity of experiment by students and student teacher should write the whole contents of the lesson on the blackboard (Figure 2 – 6).

Figure 2. One scene of the trial science lesson by a student teachre.

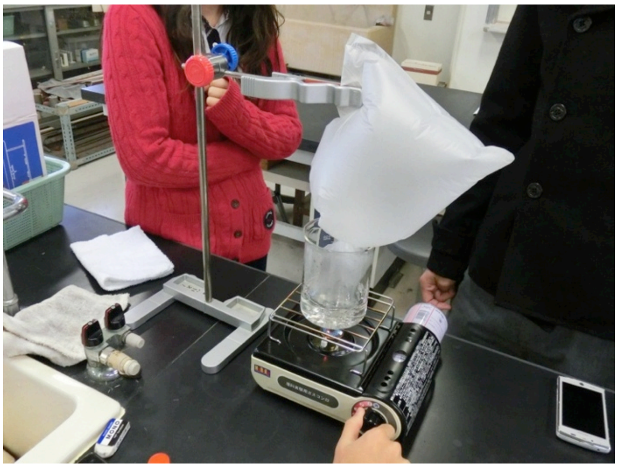

Figure 3. The experiment of vapour from boiling water in the trial science lesson.

Figure 4. The writing on the blackboard in the trial science lesson about the vapour from boiling water.

Figure 5. The experiment of ingredients change of the air after burning in the trial science lesson.

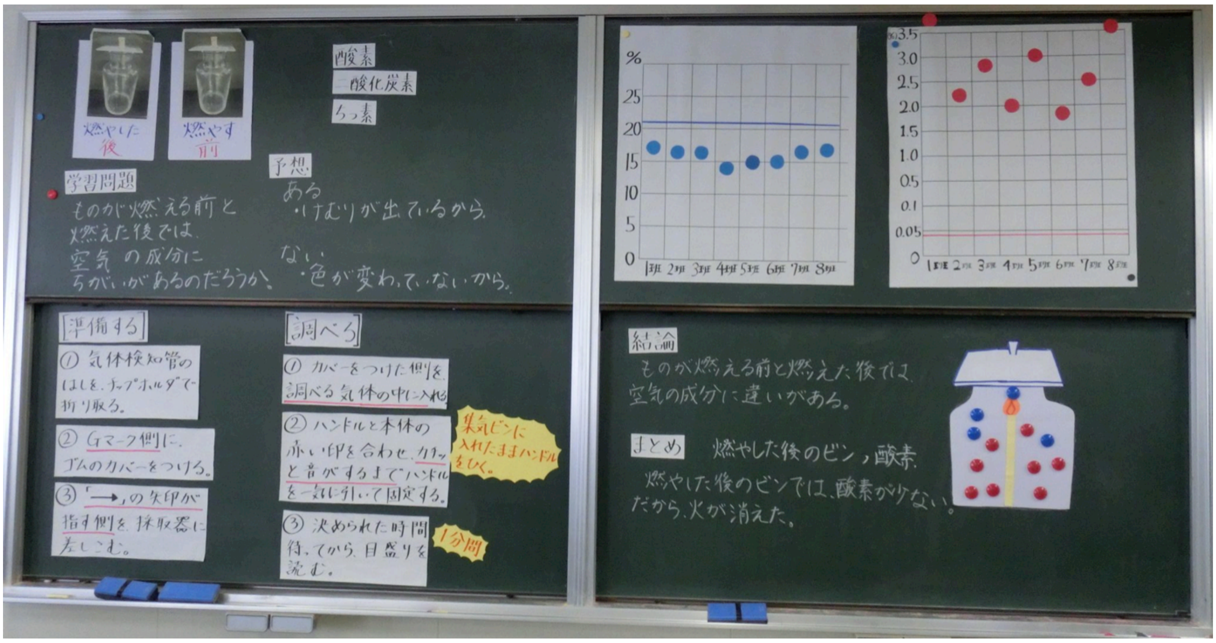

Figure 6. The writing on the blackboard in the trial science lesson about the change of the air after burning in the trial science lesson.

Immediately after the trial lesson, each student input questionnaire responses and comments to the website using their own mobile phone or PC; responses were displayed in a histogram and comments were displayed in a table on a big screen and on each student's mobile.

For the pre- and post-questionnaires, students requested to respond in writing via the website. The instructions were as follows.

(1) 'What is important for school children in primary school science lessons?' (Students respond using up to five sentences using 'Children' as the subject of the sentence.)

(2) 'Write freely about science lessons'.

RESULTS

The change in students' pre- and post-perspectives on science lessons are shown in Table 2.

A comparison of vocabulary used between all pre- and post-questionnaires shows an increase in the frequency of use of 'daily', 'experiment', 'explain', 'motivation', 'observe', 'problem', and 'safety', but a decrease in the use of 'around us' and 'understand'. In the pre-questionnaires, seven students used the term 'around us', for example, 'Children have some questions about the events around us', 'Make children relate learning with the events around us'. But at the post-questionnaire stage, no one used this phrase. The curriculum in Japan requires children to relate scientific knowledge with everyday life. Therefore, 'around us' is a familiar term for Japanese science teachers. In the pre-questionnaire, students attached more importance to everyday life and the simple understanding of phenomena than scientific enquiry and scientific explanations.

In a comparison between free comment in pre- and post-questionnaires, there was an increase in the frequency of use of 'experiment', 'explain', 'observe', and 'problem', but a decrease in the use of 'interest'. Some change in student perspectives on science lessons thus occurred in relation to these words.

Table 2

Words Used in Student Responses

What is important for children?	1st Pre	1st Post	2nd Pre	2nd Post	3rd Pre	3rd Post	4th Pre	4th Post	5th Pre	5th Post	Total -Pre	Total -Post	Free comment - pre	Free comment - post
around us	4	0	1	0	1	0	0	0	1	0	7	0	1	2
concern	3	5	1	1	2	2	2	1	0	1	8	10	4	1
daily	0	0	1	0	0	2	0	3	0	1	1	6	1	3
discover	1	2	1	0	0	0	0	0	0	0	2	2	0	2
experiment	5	5	6	15	16	13	4	7	2	11	33	51	22	27
explain	0	0	0	4	1	3	0	1	0	2	1	10	1	7
express	0	0	0	0	0	0	0	0	0	0	0	0	0	1
familiar	2	2	0	0	0	0	0	0	0	0	2	2	3	2
group	0	0	0	0	0	0	0	0	1	0	1	0	0	0
idea	11	5	3	7	7	5	1	5	3	2	25	24	13	11
interest	9	11	4	1	4	3	2	3	1	1	20	19	9	5
investigate	0	0	0	0	0	0	0	0	1	0	1	0	0	0
knowledge	0	0	1	1	1	0	2	2	1	3	5	6	3	6
living	1	0	2	0	0	2	2	2	2	1	7	5	3	4
motivation	0	1	2	3	1	1	0	2	0	3	3	10	2	1
observe	0	0	1	4	3	2	1	4	2	1	7	11	2	7
opinion	0	1	0	1	0	1	1	0	1	0	2	3	1	0
problem	5	8	5	8	3	2	1	0	2	2	16	20	9	16
question	7	9	3	5	2	4	3	2	2	0	17	20	6	7
safety	3	2	2	4	2	5	2	2	1	4	10	17	0	2
skill	0	0	0	0	2	2	0	0	0	0	2	2	2	0
thinking	0	0	0	0	1	0	0	1	0	1	1	2	2	0
understand	4	1	3	1	3	0	1	1	3	2	14	5	0	2

DISCUSSION AND CONCLUSIONS

Students more frequently used the words ‘experiment’, ‘problem’, ‘observe’, ‘safety’, ‘motivation’, ‘daily’, and ‘explain’ in their questionnaire responses after the series of lessons. In every trial lesson, the students had the opportunity to set up scientific problems and to conduct experiments or observations. This might explain why students came to use related words more frequently. Greater use of such words seems to reflect an increasing level of belief in the importance of investigative and verbal activities for schoolchildren. In contrast, student responses less often included ‘around us’ and ‘understand’; this may indicate that their area of concern became wider than those concepts imply.

In the previous study, we found that the repeated trial lesson study and immediate web-based assessment by students could make students attach greater importance to ‘conceptual change’ and so on, and developed metacognitive views of science education (Nakayama & Yamamoto, 2013). By improving the contents and process of the trial science lesson by students, students became more conscious of scientific enquiry and the linkage between scientific knowledge and everyday events. We regard that students’ perspectives on science lessons improved in that they came to reflect more scientific ways of thinking. Thus, our trial-lesson course of study supported by a Web-based feedback system was effective in several ways for educating students and can be improved further in future studies.

Acknowledgement: This work was supported by JSPS KAKENHI Grant Number 24240105.

We used the Realtime Evaluation Assistance System (REAS), a Web-based system provided by the Center of ICT and Distance Education of the Open University of Japan, Chiba. Retrieved April 21, 2014, from http://reas2.code.ouj.ac.jp/cgi-bin/WebObjects/top

REFERENCES

Driver, R., Guesne, E., & Tiberghien, A. (Eds.). (1985). Children's ideas in science. Buckingham, UK: Open University Press.

Duit, R. (1991). Students' conceptual frameworks: consequences for learning science. In S. M. Glynn, R. H. Yeany, & B. K. Britton (Eds.), The psychology of learning science. Hillsdale: Lawrence Erlbaum Associates, Hillsdale, New Jersey, US, 65–85.

Nakayama, H., & Yamamoto, T. (2013). Case study of the lesson study activity for primary school science supported by Web-based Evaluation Assistance System in the undergraduate teacher training course (1), Proceedings of ICCE 2013, Nov., 18–23, Indonesia.

DEVELOPING PRESERVICE TEACHERS' 'PRACTICAL SCIENCE TEACHING SKILLS' THROUGH LESSON STUDY

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Abstract: We developed a new course called 'Teaching Science in Grades 7–9', which offers both theoretical and practical instruction. The course gives preservice teachers (PSTs) the opportunity to plan, teach and reflect using the practice of lesson study, which is a Japanese professional development model for in-service teachers that improves the quality of teaching and learning. This research aims at investigating whether PSTs increase their 'practical science teaching skills' as a result of taking the 'Teaching Science in Grades 7–9' course. The study has three goals aimed at developing PSTs' 'practical science teaching skills': (a) PSTs will understand class flow through a five-step process: 'key question, prediction, discussion, experiment/observation and conclusion'. (b) PSTs will learn the eight elements of a lesson plan and especially how to ascertain whether the following three elements are coherent: the purpose of the class, the key question and the conclusion. PSTs will write lesson plans and teach science classes using these three coherent elements. (c) Teachers must communicate with students effectively. Therefore PSTs understand how to communicate with students, and check whether students understand the lesson contents. Both pre-tests and post-tests of this course were conducted as part of the study. Participants were required to watch the same video twice as a pre- and a post-test. Data were collected by both online monitoring and offline monitoring. Online monitoring is a way of collecting thinking-aloud data and offline monitoring is a way of collecting feedback data. We also focused on PSTs' analysis of the whole video as metacognition. The results show that the new course combining the theory and practice of lesson study is an effective way of developing PSTs' 'practical science teaching skills'.

Keywords: science teacher education, preservice teacher, lesson study, practical science teaching skills

INTRODUCTION

Preservice teachers (PSTs) are required to learn science content, pedagogical knowledge and PCK as part of their science teacher education course at university (Shulman, 1986, 1987; Van Driel, Verloop, & de Vos, 1998). Furthermore, before they take a student teaching program, PSTs need to acquire the necessary skills and knowledge to teach science effectively.

Before entering a student teaching program, the PSTs in our university are required to complete the course, 'Teaching Science in Grades 7–9', in which they learn the theory behind teaching science. Before they start their student teaching, however, most PSTs feel anxious about teaching science during their placement. As one PST comments, 'While I have learned the method of teaching science theoretically, how do I practically teach science to students?' Thus, PSTs lack experience with regards to teaching science. During the student teaching program, each cooperating teacher at the school instructs the PSTs on how to create lessons according to their own methods, which has been the traditional approach. More recently, even newly qualified teachers are required to possess the skills to teach science in Japan. It is important that university professors prepare PSTs in all aspects of teaching science, including the theory of teaching and lesson design. Moreover, it is also important to decrease the feeling of anxiety among PSTs with regards to teaching science.

The ‘Teaching Science in Grades 7–9’ course thus offers instruction in terms of organizing lessons, both theoretically and practically. Prior research studies provide some strategies for effectively preparing PSTs for teaching, including microteaching, field experience and other aspects of teaching (Davis, Petishl, & Smithey, 2006; C. Schwarz, 2009; C. V. Schwarz et al., 2008). In the present study, PSTs were given the opportunity to plan, teach and reflect using the method of teaching and the practice of lesson study. Lesson study (*kenkyuu jugyou*) is a Japanese professional development model that aims at improving the quality of teaching and learning (Inagaki & Sato, 1996; NASEM, 2009; Stigler & Hiebert, 1999). In this case, theoretical learning is based on the methodology of science education, while practical learning is based on lesson study. Thus, PSTs learn to teach science both theoretically and practically.

Our research question is as follows:

How effective is the ‘Teaching Science in Grades 7–9’ course, which combines the theory and practice of lesson study in developing teachers’ practical skills to teach science?

METHODS

Features of lesson study and its relevance to the present study

What is lesson study? Originally, lesson study aimed at improving in-service teachers’ abilities to teach science and enhance the practical element of science classes through class design and instruction. Prior to beginning a lesson study, teachers organize a team (consisting of 3–10 teachers), in which one teacher is selected to teach the class in the lesson study. The team supports the teacher in making a lesson plan and other activities. Generally, the average number of students in a class is about 35 and a varying number of teachers attend the class which is part of the lesson study as associate participants. They observe the teacher’s science class and subsequently engage in discussions concerning their teaching approach.

Generally, there are two challenges in terms of lesson study for in-service teachers: theme and points.

First, regarding the theme, each school has its own research themes and each teacher has his/her own approach to addressing these themes. Science teachers usually approach research themes with the aim of developing 1) a new teaching method, 2) educational materials, such as experimental apparatus or observational tools and 3) curriculum materials. For example, if a teacher (with the team) has developed a new teaching method, which assists students in understanding the concepts more deeply, the teacher will present this method during the lesson study. Likewise, if a teacher (with the team) has developed new experiments applicable to the lesson, the teacher will demonstrate these during the lesson study. In this way, teachers present their ideas/thoughts on one of the three aforementioned approaches.

Second, regarding the points, teachers discuss five points in a lesson study:

(1) The aim of the class: Is it appropriate?

(2) The lesson plan: Does it represent what the teacher wants to teach?

(3) Lesson evaluation: Do the students understand the topic? Does the teacher engage the students? Does the teacher foster a positive class environment?

(4) Following the class, the teacher, team and associate participants evaluate the positive and

negative aspects of the lesson. They discuss ideas for improving the science class, ensuring that all the negative aspects of the lesson are addressed.

(5) The teacher and associate participants learn how to improve their science classes using the information learned from points 1–4 of this process.

In the current study, the main emphasis is on the training of PSTs using lesson studies. As they are still third-year university students, we have focused only on the points because they do not have the experience to work on issues related to the theme, such as developing new teaching methods, experiments or curricula.

The goals of taking the course “Teaching Science in Grades 7–9’

During lesson studies, which are part of ‘Teaching Science in G 7–9’, PSTs are required to engage in planning, teaching and reflecting within the scope of five points. As PSTs still have many things to learn, we have developed three goals to assist them through this process:

(1) PSTs should understand class flow through a five-step process, which include key question, prediction, discussion, experiment/observation and conclusion. As students conduct experiments or observations in science classes that address the key question, they need to make a prediction prior to performing these experiments/observations. Sometimes the students will have different views than that of their classmates. As a result, they are required to engage in a debate and reach a conclusion. It is therefore important for PSTs to study the class flow, both theoretically and practically.

(2) PSTs learn the eight elements of a lesson plan (Table 1) and how to ascertain whether the following three elements are coherent: No.1 the purpose of the class, No.3 the key question, and No.8 the conclusion. Therefore, when PSTs observe their colleagues’ classes, they read their peers’ purpose of the class, evaluate whether the students achieve the goal when they attempt to answer the key question, check the conclusion and then determine whether coherency exists between the three aforementioned elements.

(3) Teachers must communicate effectively with students. PSTs aren’t professional teacher yet. Therefore, PSTs need to understand how to engage students and check whether they understand the lesson’s content. They also should possess the ability to motivate students.

Table 1. Eight elements of a lesson plan.

No.	Assessment criteria of lesson plan
1	The purpose of the class
2	Apparatus and chemicals
3	What is a key question?
4	Flow of class: five steps
5	Important reminder (teaching process, prevention of accidents)
6	Teacher’s movement
7	Student’s movement
8	Conclusion

Every PST is required to participate in three lesson studies as part of the ‘Teaching Science in Grades 7–9 course: Lesson Studies 1, 2 and 3’. The PSTs focus on the three goals listed above as they teach as this aims at helping them in developing their practical science teaching skills.

Participants

Forty-five PSTs attended the ‘Teaching Science in Grades 7–9’ course conducted during the first semester (Fig. 1: Fifth semester) in 2013. Thirteen PSTs (six male and seven female) were randomly selected as participants. Data for this study were obtained only from these participants.

Lesson study scenarios

(1) One PST teaches science to his/her colleagues, rather than to middle school students, in this course. Therefore, the PSTs play the role of both teacher and a middle-school student. For the purpose of this study, the lesson study of PSTs differs to that of in-service teachers, for whom lesson studies focus on the teachers in an actual classroom setting with their students.

(2) Each PST plays the role of science teacher once in the lesson studies.

(3) The group divides into fifteen teams, with three PSTs forming each team (45÷3 = 15). Each PST is required to participate in three lesson studies.

(4) The lesson runs for 10 minutes rather than the standard 45- or 50-minute classroom lesson.

(5) After observing a science class, the PSTs (as associate participants) ask questions. The PST (who played the science teacher or team) answers questions about the science class and everyone discusses any problems which came up regarding the class.

(6) The author of this study and the teaching assistants offer clear guidance on how to improve the science class.

Data collection

This research aims at investigating whether PSTs increase their practical science teaching skills as a result of completing the ‘Teaching Science in Grades 7–9’ course. Both pre-tests and post-tests are conducted as part of this study. In the pre-test, participants are required to watch a 45-minute video of a science class in which the teacher and students appear (Grade 6, study of leverage theory). Using this video, we collect two kinds of data through two methods: online monitoring and offline monitoring (Sato, Akita, Iwatake, & Yosimura, 1992; Sato, Iwakawa, & Akita, 1991).

(1) Online monitoring: The PSTs’ thinking aloud comments are recorded using an IC recorder as they watch the video, which is not replayed. Then the recorded voices are converted into documents. This is called the thinking aloud data.

(2) Offline monitoring: After watching the video, the PSTs write an evaluation of the science class shown in the video. This is called the feedback data.

Then in the post-test, participants also watch the same video, and the two forms of data are collected again. Both online and offline monitoring systems are used as part of this study. The online monitoring system captures participants’ thoughts as they watch the class, while the offline monitoring system reflects their views after they have watched the class. Thus, we collect the following four types of data:

1) Thinking aloud in pre-test
2) Feedback during pre-test
3) Thinking aloud in post-test
4) Feedback during post-test

We compare the pre-test and the post-test of the thinking aloud comments. Regarding the thinking aloud data, first, the number of sentences and words are compared. The sentences are then classified into six categories. We count the number of sentences in each category. Next, we analyse the feedback received. In the post-test, each PST independently compares the evaluation between pre-test and post-test feedback and writes a self-appraisal. Thus, we do not compare pre-test and post-test feedback; rather, we focus on self-appraisal in the post-test. Generally a self-appraisal is part of metacognition. Therefore, a metacognitive analysis is then performed on the post-test feedback.

RESULTS

Pre-test and post-test perceptions: Comparison

(1) The number of sentences and words

We calculated the average numbers of words and sentences during the pre-test and the post-test (Table 2).

Table 2. Comparison of pre-test and post-test thinking aloud: numbers of sentences and words.

	Pre-test	Post-test	Factor
	(1)	(2)	(3) = (2) ÷ (1)
Sentences	39.2	44.8	1.14
Words	578.0	949.4	1.64

(2) Six categories and the variation of PSTs' thinking aloud

The contents of thinking aloud were separated into three items: teacher, students and others. The teacher items were divided into three categories: observation of teacher's behaviour (=T obs.), improvement in teacher instruction (=T imp.), and flow of teacher's instruction (=T flow). Student items were divided into two categories: the observation of students' behaviour (=S obs.) and the understanding of the flow of the science class (=S flow) (Table 3).

Table 3. Six categories and their variations.

Item	Category	Content	Example
Teacher	T obs.	Observation of a teacher's behaviour. The things you can tell by looking at and listening to a teacher.	The teacher has a loud voice or the teacher writes well on the blackboard.
	T imp.	Improvement in teacher instruction. PSTs aim at developing a better method than the teacher in this class.	The teacher should have prepared an easier experiment, as this one was too difficult for the students.
	T flow	Flow of the teacher's instruction. Do PSTs understand the five steps of class flow?	The teacher asked the key question and developed a prediction. The teacher was encouraging towards the students while they performed their experiments.
Student	S obs.	Observation of students' behaviour. The things you can tell just by looking at and listening to a teacher.	Some students take notes, while others do not.
	S flow	The understanding of flow of the science class. Students understand the class flow.	The student wrote a conclusion followed by the results. She understands the flow of a science class.
Other		Other	Aha! I see.

The averages of the six categories of the 13 PSTs’ thinking aloud are compared between the pre-test and the post-test in Figure 1.

The majority of items relate to the teacher, accounting for 81.4% of items in the pre-test and 86.4% in the post-test. Therefore, we concentrate on the three categories of teacher items. Although the percentage of ‘T obs.’ decreased, the percentage of ‘T imp.’ and ‘T flow’ increased. On closer examination, the 13 PSTs can be divided into three patterns of reaction regarding their thinking aloud concerning the teacher items. In the post-test, 6 PSTs increase the ‘T imp.’ category, 4 increase the ‘T flow’ category and 2 increase both the ‘T imp.’ and the ‘T flow’ categories (Figures 2, 3 and 4 respectively).

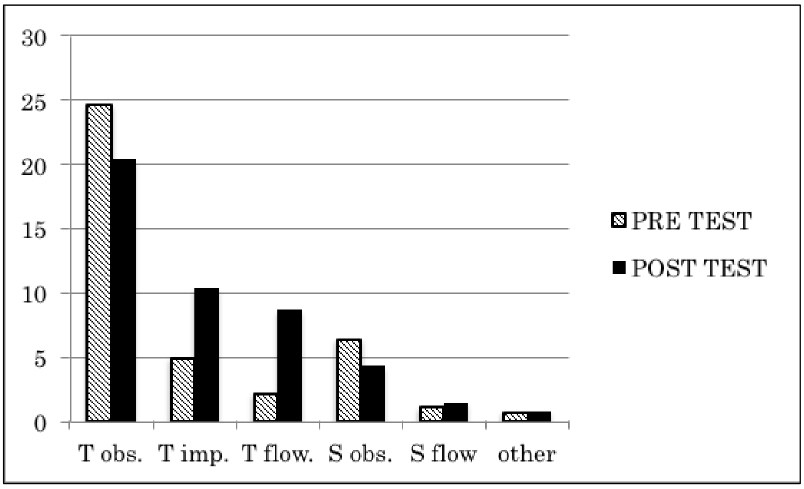

Figure 1. Average of the six categories between pre-test and post-test perceptions.

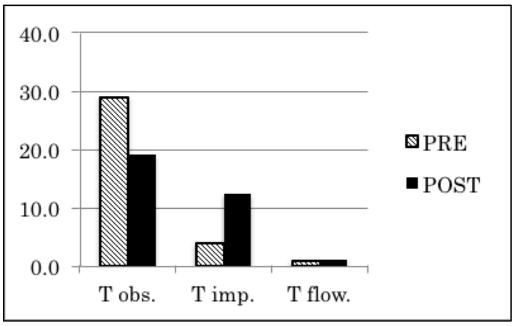

Figure 2. ‘T imp.’ pattern.

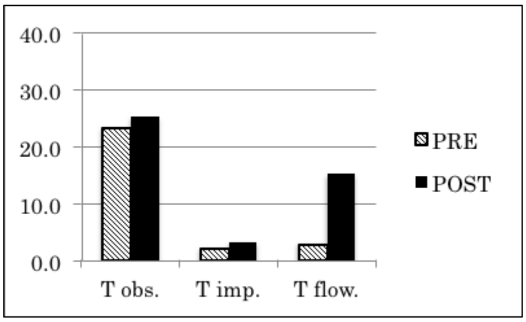

Figure 3. ‘T flow’ pattern.

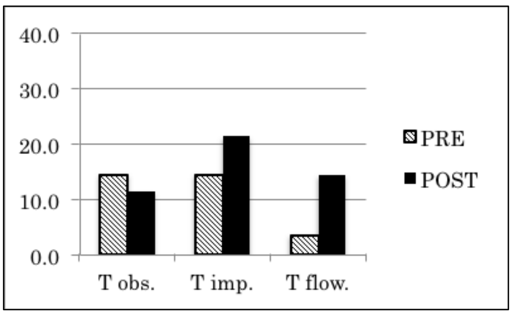

Figure 4. ‘T imp. + T flow’ pattern.

Analysis of the metacognition of post-test feedback

Five out of thirteen PSTs compared between pre-test and post-test, then one of them wrote his development; they also wrote an analysis of the science class video in the pre-test and the post-test. Here we focus on their development, because they are based on self-appraisals and represent their growth. These are also metacognition from the feedback. Therefore, we determine where the 5 PSTs belong in the pattern of thinking aloud. The data was subsequently analysed to ascertain whether the analysis of post-test feedback corresponded with PSTs' perceptions of pre-test. As a result, we found that comments pattern of pre-test of the five students are the same as the pattern of the post-test (Table.4).

Table 4. Metacognitive analysis of post-test feedback and PSTs' perceptions.

PST's name	Thinking aloud	Record of feedback	Feed back
S2	T imp.	'…because I saw many good points in this science class during the pre-test, I thought I wanted to teach science like this teacher. However, during the post-test, I found many more good points and areas for improvement than in the pre-test. I think I can teach science better than before. …'	T imp.
S4	T flow	'…I think my understanding of undertaking a class evaluation in the post-test is very different from my understanding in the pre-test. During the pre-test, I focused on the teacher's behaviour, the size of words on the blackboard, the teacher's picture-based explanations, her tone of voice and other things. But during the post-test, I focused on the class flow: key question, prediction, discussion, experiment, and conclusion. I also focused on whether the teacher engaged students in science or not. …'	T flow
S5	T imp. + T flow	'…During the pre-test, I did not understand how to observe the teachers. At present, I am surprised how I have changed. Before, I would focus on how the teacher taught science from moment to moment. So, I only observed the teacher's behaviour during part of the class, and I only really pointed out the problems. However, through lesson studies, I have come to understand class flow and the need for coherence among the following three points: the class purpose, key question and the conclusion. Each team analysed the lesson plan and observed our science class. We encouraged each other to promote lesson planning'.	T imp. + T flow

DISCUSSION AND CONCLUSION

Comparison of pre-test and post-test thinking aloud

(1) The numbers of sentences and words

We investigated the numbers of words and sentences regarding participants' thinking aloud. The numbers of sentences in the post-test are 1.14 times higher than those in the pre-test. There is little difference regarding the sentences between the pre-test and the post-test. However, the number of words in the post-test are 1.64 times higher than those in the pre-test; this means that the sentences are much longer in the post-test.

(2) Six categories of perceptions

The thinking aloud was divided into six categories. We specifically focused on three categories related to teacher items. The percentage of ‘T obs.’ decreased, while the percentage of ‘T imp.’ and ‘T flow’ increased. ‘T obs.’ refers to a superficial understanding of the teachers’ behaviour. However, ‘T imp.’ and ‘T flow’ represent their views more deeply, as ‘T imp.’ shows their views on how teachers teach science effectively through observing students’ behaviour in a class and ‘T flow’ represents their perceptions of the class flow.

The results indicate that the new course combining the theory and practice of lesson study is an effective way of developing PSTs’ ‘practical science teaching skills’. Three patterns were found to develop the skills of PSTs: the ‘T imp.’ pattern, the ‘T flow’ pattern and the ‘T imp. + T flow’ pattern.

Analysis of the metacognition of feedback in the post-test

We analysed the metacognition of feedback in the post-test (Table 4). We evaluated that PSTs of the ‘T imp.’ pattern of thinking aloud wrote feedback as the ‘T imp.’ pattern. We also evaluated that the PST of the ‘T flow’ pattern of thinking aloud wrote feedback as ‘T flow’. The PST of the ‘T imp. + T flow’ pattern wrote feedback as the ‘T imp. + T flow’ pattern. Thus, PSTs’ reflections in thinking aloud while watching the video were very close to the metacognition of feedback.

The ‘Teaching Science in Grades 7–9’ course comprises three goals: (1) understanding class flow; (2) ensuring coherence between the purpose of the class, the key question and the conclusion’ and (3) effective communication with students (see pages 3 and 4 of this paper). The results show that PSTs of the ‘T imp.’ pattern master goal (3); PSTs of the ‘T flow’ pattern master goals (1) and (2) and PSTs of the ‘T imp. + T flow’ pattern master goals (1), (2) and (3).

Therefore, PSTs understand and master the practical skills necessary to teach science based on the three patterns. Thus, the ‘Teaching Science in Grades 7–9’ course, which combines the theory and practice of lesson study, is effective in developing PSTs’ practical science teaching skills. We found that three patterns are relevant to developing the skills of PSTs: (1) improvement in teacher instruction, (2) flow of the teacher’s instruction and (3) a mixture of both the improvement and flow of the teacher’s instruction.

REFERENCES

Davis, E. A., Petishl, D., & Smithey, J. (2006). Challenges New Science Teachers Face. *Review of Educational Research Winter, 76*(4), 607–651.

Inagaki, T., & Sato, M. (1996). *Introduction of Lesson Study (in Japanese)*. Tokyo: Iwanami Shoten.

NASEM, National Association for the Study of Educational Methods. (2009). *Lesson Study in Japan*. Tokyo: Gakubunsha.

Sato, M., Akita, Kiyomi, Iwatake, N., & Yosimura, T. (1992). Practical Thinking Styles of Teachers--A Lesson of Descriptive Inquiry on Thought Processes. *Bulletin of The Faculty of Education The University of Tokyo, 31*, 183–200.

Sato, Manabu, Iwakawa, Naoki, & Akita, Kiyomi. (1991). Partical Thinking Styles of Teachers: Comparing Experts' Monitoring Processes with Novices. *Bulletin of The Faculty of Education The University of Tokyo, 30*, 177–198.

Schwarz, C. (2009). Developing preservice elementary teachers' knowledge and practices through modelling-centred scientific inquiry. *Science Education, 93*(4), 720–744.

Schwarz, C. V., Gunckel, K. L., Smith, E. L., Covitt, B. A., Bae, M., Enfield, M., et al. (2008). Helping elementary preservice teachers learn to use curriculum materials for effective science teaching. *Science Education*, *92*(2), 345–377.

Shulman, L. S. (1986). Those who understand: Knowledge growth in teachng *Educational Reseacher, 15*, 4–14.

Shulman, L. S. (1987). Knowledge and teaching: Foundations of the new reform. *Harvard Educational Review, 57*(1), 1–22.

Stigler, J. W., & Hiebert, J. (1999). *The Teaching Gap: Best Ideas from the World's Teachers for Improving Education in the Classroom*. New York: Free Press.

Van Driel, J. H., Verloop, N., & de Vos, W. (1998). Developing science teachers' pedagogical content knowledge. *Journal of Research in Science Teaching*, *35*(6), 673–695.

THE CONSISTENCY BETWEEN PRESERVICE TEACHERS' EPISTEMOLOGICAL BELIEFS AND INSTRUCTIONAL STRATEGIES

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Abstract: The purpose of this study is to investigate the consistency between preservice science teachers' epistemological views and their classroom practices. Five senior preservice science teachers were interviewed to explore their epistemological beliefs. Their classroom practices were also observed to find out the instructional strategies they utilized to teach science. Constant-comparative method of data analysis and cross-case analysis was conducted by two independent researchers. Constructivist, positivist, and mixed categories were used to identify epistemological views for each epistemological view dimension separately. After elucidating preservice science teachers' epistemological views, their classroom practices were investigated. The analysis of observation records of classroom practices yielded four different instructional strategies used by them. These were lecturing, questioning, laboratory work, and small group work. Overall it can be concluded that there is a good coherence between PSTs' epistemological views and their classroom practices. PST having positivist epistemological views implemented more lecturing and teacher-led classroom activities and discussions. Other PSTs who were more constructivists in their epistemological beliefs tried to use more student-centered strategies and student-guided small group activities. The results were discussed.

Keywords: Epistemological beliefs, instructional strategies, classroom observation.

EPISTEMOLOGICAL BELIEFS

After the second half of the 20th century, epistemological issues were at the center of philosophical studies rather than educational ones. In the late 20th century, epistemology is concerned in educational studies. The shift of epistemological issues towards educational issues was due to the influence of those beliefs on reading, writing, comprehension, interpretation, and learning (Ryan, 1984; Schommer, 1990; Kardash & Scholes, 1996). Qian and Alvermann (1995) stated that epistemological views about knowledge affect students' success in difficult cognitive processes such as conceptual change. Hofer (2001) added that students' beliefs are included in the process of learning. This is the reason of focusing on beliefs about knowledge and knowing and she continues "What students think knowledge is and how they think they know have become critical components of understanding student learning" (Hofer, 2001, p. 354).

Epistemology is defined as an area that focuses on human knowledge (Hofer, & Pintrich 1997). Hofer and Pintrich (1997) stated that epistemology is about nature and justification of human knowledge. The studies on epistemological issues began with Perry in early 1950s suggesting a developmental perspective on students' epistemological beliefs. Perry's study (1970) on intellectual and ethical development was the first to trigger research on epistemological development although it does not focus on epistemology specifically. The model of Belenky, Clinchy, Goldberger, and Tarule (1986) was a criticism towards Perry's since Perry (1970) used mainly males in his study and generalized the findings to all college students. Belenky et al. (1986) were interested in how woman know and learn and also how they see the reality is another concern of their study. Another epistemological theory emphasized is Epistemological Reflection

Model. It is developed by Magolda (1992) after a 5-year longitudinal study. She mainly focused on gender relations in epistemological development and how students make meaning under the influence of epistemological assumptions. How epistemological assumptions affect the students' "ways of knowing" was reported in this study. Unlike Belenky et al. (1986) and Perry (1970), Magolda (1992) emphasizes the nature of learning within her epistemology understanding. Her sample was consisted of almost equal numbers of men and women and she studied the epistemological development patterns of both gender. Her findings were closely aligned with those of Belenky et al.'s (1986) in terms of gender aspect of knowing. The other model was Reflective Judgment Model developed by King and Kitchener (1994). It focused on the epistemic assumptions that affect the reasoning process. This model has seven stages classified within three levels. Within first stage, individuals see knowledge as simple, concrete, certain. They also believe that knowledge necessitates no justification. Individuals accept what authority says as true or wrong. Throughout the process, individuals realize that knowledge may be uncertain, abstract and complex also they believe that knowledge may require justification and critical evaluation. The models described so far shaped the research on epistemological beliefs or personal epistemology (Schommer, 1990). Schommer (1990) provided initial evidence for the definition of epistemological beliefs. She criticized taking epistemological beliefs as unidimensional and suggested multidimensional characteristic of epistemological beliefs (Schommer, 1994). She redefined epistemological beliefs as a system of more or less independent beliefs. By system she means that there is more than one belief to consider and by more or less independent, she means that individuals may be sophisticated in some beliefs, but not in others. It means that epistemological beliefs do not develop synchronously.

Having given the base for epistemological beliefs, it is appropriate to focus on nature of science. Lederman (1992) defines nature of science as the epistemology of science which refers to science as a way of knowing. He also adds that nature of science is the values and beliefs existing as a natural part of the development of scientific knowledge.

To develop students' understanding of the nature of science is essential for science education and teachers are required to achieve this goal. Research findings suggest that conceptions about nature of science are one of the factors that influence learning. However, they affect not only learning but also teaching. The study of students' conceptions of the nature of science began in twentieth century and resulted in a generalization that students do not have sufficient understanding of the nature of science. As Lederman (1992) stated that this conclusion led to the research studies in curriculum improvement and the teacher improvement. It is important to focus on teachers because teachers' conceptions about nature of science may influence students' conceptions of nature of science. Moreover it may have an impact on their classroom practices. Thus epistemological views have become an important issue in teaching.

However, science teachers do not seem to have an adequate understanding of the nature of science. There are some studies that try to enhance teachers' views about nature of science by utilizing different methodologies in method courses during teacher education programs (Barufaldi, Bethel, & Lamb, 1977; Bianchini & Colburn, 2000; Akerson, Abd-El-Khalick, & Lederman, 2000). Recent research has emphasized the role of teachers by focusing on their conceptions and classroom practice. It is evident that teachers should have an adequate nature of science views to teach about it more effectively. However, although they have sophisticated views about nature of science they cannot translate into their classroom practice. Abd-El-Khalick, Bell, and Lederman (1998) came to the conclusion that preservice secondary science teachers could not achieve the translation of their nature of science views into their classroom practices.

In this sense, there are two lines of research about the relationship between teachers' nature of science views which refers to epistemological views for this study and their classroom practices. One line of the research highlighted that there exists an impact of teachers' epistemological views on their classroom practice (Brickhouse, 1989; Linder, 1992; Tsai, 2002; 2006; Hashweh, 1996; Chan & Elliott, 2000). Brickhouse (1989) found that teachers' epistemological views are coherent with their behaviors in the classroom. The study of Tsai (2002) explores the science teachers' views about teaching, learning and science and finds out the relationships among them. Teachers' scientific epistemological views towards teaching, learning and science are called as "nested epistemologies" in her study since a close relationship was found between those three belief systems. Other research findings also support the relationship between epistemological views and teaching practice. Chan and Elliott (2000) imply that epistemological views may be a key factor in learning how to teach. Hashweh (1996) described teachers as having constructivist scientific epistemological views and empiricist ones. The author concluded that teachers having constructivist scientific epistemological views have utilized more and different instructional strategies to promote conceptual change when compared to the teachers' having empiricist views. Moreover they are more competent in conceptual change by using effective strategies.

The other line of research argues that teachers' epistemological views are not directly related to their classroom practices (Benson, 1989; Duschl and Wright, 1989; Lederman and Zeidler, 1987; Mellado, 1997). There are other factors that influence teachers' classroom practices. Mellado (1997) concluded that it would be too simple to focus on only teachers' epistemological views as an explanation of their classroom practices. However we believe that teachers' beliefs about knowledge and knowing may be elucidatory for their teaching.

METHOD

The purpose of this study is to investigate the relation between preservice science teachers' (PST) epistemological views and their classroom practices. This study was carried out with 5 PSTs. Their most important characteristics were that they took science method courses that include the aspects of nature science and teaching about nature of science. Data collection was done through interviewing about epistemological view dimensions and observing their classroom practices. The epistemological view dimensions were theory-laden nature of scientific knowledge, the invented and creative nature of scientific knowledge, changing and tentative nature of scientific knowledge, the role of social negotiation in science community, and the cultural impacts on science. To collect data about classroom practice, each PST was observed for two classroom hours.

Constant-comparative method of data analysis and cross-case analysis was conducted by two independent researchers. Constructivist, positivist, and mixed categories were used to identify PSTs' epistemological views for each epistemological view dimension separately because as Schommer (1994) emphasized individuals may have sophisticated beliefs for some dimensions but not necessarily for the others. After elucidating PSTs' epistemological views, their classroom practices were investigated. The analysis of observation records of classroom practices yielded four different instructional strategies used by them. These were lecturing, questioning, laboratory work, and small group work.

RESULT

The effect of PSTs' epistemological views on their classroom practice was examined in this study. The epistemological views profiles of all PSTs across five dimensions and the instructional strategies they used were summarized in Table 1.

Table 1. PSTs' epistemological views and their preference of instructional strategies

	Theory-laden nature of scientific knowledge	Invented and creative nature of scientific knowledge	Changing and tentative nature of scientific knowledge	The role of social negotiation in science community	Cultural impacts on science	Instructional Strategies
PST1	Constructivist	Constructivist	Constructivist	Mixed	Constructivist	Laboratory & Small Group Work
PST2	Constructivist	Constructivist	Constructivist	Mixed	Constructivist	Laboratory & Small Group Work
PST3	Constructivist	Constructivist	Constructivist	Mixed	Constructivist	Laboratory & Small Group Work
PST4	Positivist	Positivist	Positivist	Mixed	Positivist	Lecturing & Questioning
PST5	Constructivist	Constructivist	Constructivist	Constructivist	Constructivist	Laboratory & Small Group Work

In terms of the interview responses of five PSTs, three of them held constructivist views on all epistemological view dimensions except the role of social negotiation in development of scientific knowledge. One PST expressed constructivist views for all epistemological view dimensions. And one PST stated positivist views for theory-laden nature of scientific knowledge, the invented and creative nature of scientific knowledge, changing and tentative nature of scientific knowledge, and the cultural impacts on science while he hold mixed views for the role of social negotiation in science community. To exemplify, when asked about the theory laden nature of scientific knowledge, PST 1 held a constructivist position by stating as:

> Theory plays a role on scientist both exploration and observation. For example if a scientist makes his/her study on evolutionary theory, he/she will make his/her observation taking into account of Darwin's point of view and studies. Scientists have expectations before conducting their exploration. The reason why they conduct exploration is to find an answer to a problem or a question. Therefore they make their observation based on their expectation.

However when he asked about the role of social negotiation, he had a mixed view because he expressed that

> I can say that scientists' study may be influenced by other scientists' study. Science is sometimes an individual exploration and sometimes group exploration. They try to understand underlying principles of other's findings. If that research related to their research area then scientists examine others' research findings in detail.

Consistent with his beliefs, PST1 implemented more constructivist instructional strategies in his classroom. He utilized laboratory work to enable students test the hypothesis they formed, make observations, collect data and reach a conclusion. However his style was not like a "cookbook" approach. He rather preferred students to discover by themselves. He also utilized small group work and allowed students share their ideas and reach a conclusion together.

PST4 was more positivist regarding epistemological view dimensions. He mostly expressed that development of scientific knowledge is not affected by the scientists' background and existing theories. Moreover, he believed that scientific knowledge is durable. His views for cultural impacts on science were also reflected the positivist epistemological view. He believed that science should be cultural free otherwise, there cannot be universal science.

In terms of instructional strategies, PST 4 was generally utilized lecturing and questioning. He acted as a source of knowledge and asked students questions if they understood the subject. He told his students to memorize some definitions and formulas to solve the problems.

DISCUSSION

This study aimed to investigate the consistency between PSTs' epistemological views and classroom practices. Data were collected through interviewing with five PST and making classroom observations. Overall it can be concluded that there is a good coherence between PSTs' epistemological views and their classroom practices. PST having positivist epistemological views implemented more lecturing and teacher-led classroom activities and discussions. Other PSTs who were more constructivists in their epistemological beliefs tried to use more student-centered strategies and student-guided small group activities. The consistency between PSTs' epistemological views and the instructional strategy they used may be due to the fact that they previously learned about nature of science, epistemological views and the teaching methods consistent with these views. However one PST still held positivist epistemological views consistent with his teaching science. This result may be due to his previous beliefs and experiences about scientific knowledge and teaching science because his science teacher in middle school also taught science in the same way.

REFERENCES

Abd-El-Khalick, F., Bell, R. L., & Lederman, N. G. (1998). The nature of science and instructional practice: Making the unnatural natural. *Science Education, 82,* 417 – 436.

Akerson, V.L., Abd-El-Khalick, F. and Lederman, N.G. (2000). Influence of a reflective explicit activity-based approach on elementary teachers' conceptions of nature of science. *Journal of Research in Science Teaching, 37*, 295–317.

Barufaldi, J. P., Bethel, L. J., & Lamb, W. G. (1977). The effect of a science methods course on the philosophical view of science among elementary education majors. *Journal of Research in Science Teaching, 14,* 289 – 294.

Baxter Magolda, M. B. (1992). *Knowing and reasoning in college: Gender-related patters in students' intellectual development.* San Francisco: Jossey-Bass.

Belenky, M. F., Clinchy, B. M., Goldberger, N. R., & Tarule, J. M. (1986). *Women's ways of knowing: The development of self, voice and mind.* New York: Basic Books.

Benson, G. D. (1989). Epistemology and science curriculum. *Journal of Curriculum Studies, 21,* 329 – 344.

Bianchini, J. A., & Colburn, A. (2000). Teaching the nature of science through inquiry to prospective elementary teachers: A tale of two researchers. *Journal of Research in Science Teaching, 37,* 177 – 209.

Brickhouse, N. W. (1989). The teaching of the philosophy of science in secondary classrooms: Case studies of teachers' personal theories. *International Journal of Science Education, 11,* 437 – 449.

Duschl, R. A., & Wright, E. (1989). A case study of high school teachers' decision making models for planning and teaching science. *Journal of Research in Science Teaching, 26,* 467 – 501.

Hashweh, M. Z. (1996). Effects of science teachers' epistemological beliefs in teaching. *Journal of Research in Science Teaching, 33,* 47 – 63.

Hofer, B. K., & Pintrich, P. R. (1997). The development of epistemological theories: Beliefs about knowledge and knowing and their relation to learning. *Review of Educational Research, 67,* 88-140.

Hofer, B. K. (2001). Personal epistemology research: Implications for learning and teaching. *Journal of Educational Psychology Review, 13,* 353-383.

Kardash, C. M., & Scholes, R. J. (1996). Effects of preexisting beliefs, epistemological beliefs, and need for cognition on interpretation of controversial issues. *Journal of Educational Psychology*, *88,* 260-271

King, P. M. & Kitchener, K. S. (1994). *Developing reflective judgment: Understanding and promoting intellectual growth and critical thinking in adolescents and adults*. San Francisco: Jossey-Bass.

Lederman, N. G. (1992). Students' and teachers' conceptions of the nature of science: A review of the research. *Journal of Research in Science Teaching, 29,* 331 – 359.

Lederman, N. G., & Zeidler, D. L. (1987). Science teachers' conceptions of the nature of science: Do they really influence teaching behavior? *Science Education, 71,* 721 – 734.

Linder, C. J. (1992). Is teacher-reflected epistemology a source of conceptual difficulty in physics? *International Journal of Science Education, 14,* 111 – 121.
Mellado, V. (1997). Preservice teachers’ classroom practice and their conceptions of the nature of science. *Science Education, 6,* 331 – 354.
Perry, W. G. (1970). *Forms of intellectual and ethical development in the college years: A scheme.* New York: Holt, Rinehart and Winston.
Ryan, M. P. (1984). Monitoring text comprehension: Individual differences in epistemological standards. *Journal of Educational Psychology*, *76*, 248-258
Qian, G. & Alvermann, D. (1995). Role of epistemological beliefs and learned helplessness in secondary school students’ learning science concepts from text. *Journal of Educational Psychology, 87*, 282-292.
Schommer, M. (1990). Effects of beliefs about the nature of knowledge on comprehension. *Journal of Educational Psychology, 82*, 498-504.
Schommer, M. (1994). Synthesizing epistemological belief research: Tentative understandings and provocative confusions. *Educational Psychological Review*, *6*, 293-319.
Tsai, C.-C. (2002). Nested epistemologies: Science teachers’ beliefs of teaching, learning and science. *International Journal of Science Education, 24,* 771-783.

SUCCESSFUL UNIVERSITY-SCHOOL PARTNERSHIPS - AN INTERPRETIVE FRAMEWORK

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Abstract: This paper presents a research-informed Interpretive Framework (IF) for initiating, implementing and evaluating university-school partnerships in science teacher education. The notion of partnerships between universities and schools is long established, and yet the term 'partnership' remains ill defined. The two-year study of five different partnership models within science education course work reported here, led to the development of the IF to help address this issue. The IF exemplifies, contextualizes and summarizes the practices of successful university-school partnerships in science teacher education. It is informed by a multiple case study of five universities comprising questionnaires and interviews with pre-service teachers, classroom teachers, school principals, and teacher educators within and external to the universities involved. An iterative approach was taken to data collection and analysis, ultimately leading to the framework presented in this paper. The four-part framework provides a set of 'Guiding Pedagogical Principles', a model and set of action tools for 'Growing University-School Partnerships' (GUSP), a three-part typology showing different 'Representations of Partnership Practice' (RPP), and a 'Growth Model' to illuminate how pre-service teacher education is enhanced through effective university-school partnerships. This framework is timely in the current milieu of partnership practice to address long-held concerns about the nature and quality of teacher education. Within the science context it also helps to address equally long-lasting concerns about pre-service teachers' exposure to quality science teaching during the traditional practicum period of their course. Key to our findings is the importance of each stakeholder's role within the partnership, as well as a valuing of different partnership types – from connective to collaborative. Since its inception the IF has been used in education contexts outside of science, as well as with industry-based partners. This uptake highlights the need for such a framework to inform partnership work, as well as illustrating its transferability across contexts.

Keywords Partnership, Teacher Education, Science teacher education, Interpretive Framework

INTRODUCTION

University-school partnerships

The notion of university-school partnerships is currently dominating international discourses around teacher education. This growing predominance stems from widespread criticisms about the quality of teacher education, where universities are increasingly thought to be overly theoretical and limited in their effectiveness to prepare pre-service teachers for the "real world" of the classroom. Moreover, there are concerns that pre-service teachers are too isolated from their peers and universities when they are in schools (Darling-Hammond, 2006; Gorodetsky & Barak, 2008) and are left to determine how to connect their coursework with the practical component of their teacher preparation. This disconnect leads to what is commonly referred to as the 'theory-practice divide'.

One resounding answer to these and other criticisms surrounding teacher education is the notion of partnerships between universities and schools. Partnerships are thought to be able to provide increased opportunities and support for pre-service teachers to connect theory and practice (Zeichner, 2010). One of the outcomes stemming from this, however, is an increasing uncertainty around the roles of the different stakeholders and of the meaning of the term "partnership". Questions that can arise include who will take primary responsibility and assessment for pre-service teachers? Should there be a liaison person, a boundary crosser, who is cognizant of both the university and the school-based experiences? Or, as some have queried, should there be an apprentice-based model that questions whether the teacher educator is required at all? The lack of consensus around the meaning of partnership, and the role of key stakeholders within them, is one of the inchoate issues stemming from the emergence of university-school partnerships. With partnerships being presented almost as the panacea for that which afflicts teacher education, it is becoming increasingly paramount that a systematic way of defining partnerships and the roles within them is established. This paper presents such a systematic way of approaching partnerships in teacher education stemming from a research-informed Interpretive Framework (IF) associated with a science teacher education project that explored the establishment, growth and sustainability of university-school partnerships.

Partnerships and science teacher education

The need for university-school partnerships within science teacher education is arguably more an imperative than for teacher education more generally. This is because of well-established concerns around the teaching of science in schools, particularly in the primary (five-twelve age group) sector. Teachers' lack of knowledge in background science concepts and low confidence in their ability to teach science effectively has long been associated with limited quality and quantity of science teaching in the primary years (e.g. Goodrum, Hackling, & Rennie, 2001). This issue means that primary pre-service teachers have limited exposure to observe and teach science during standard practicum placements. This lack of exposure presents science teacher educators with a challenge in linking theory and practice within their coursework, a concern that is exacerbated by the unique strategies and approaches science requires for effective teaching, and which are this less likely to be observed or practiced through other curriculum areas. The lack of exposure to and experience of science teaching leads to an escalation of poor experiences and negative attitudes towards science. The key to overcoming this issue is by embedding a science-teaching experience within science education coursework rather than hoping for unlikely and unreliable exposure to science within the traditional practicum placement.

Some studies have shown that engaging pre-service teachers in supported science teaching experiences helps to build self-efficacy beliefs in their ability to teach science (Jones, 2010; Kenny, 2010). Palmer (2006) has also found that science teaching experiences that follow science education units, or science professional learning (Palmer, 2011), help to increase pre-service and in-service teachers' science teaching confidence respectively. These studies demonstrate the success of what Bandura (1977), in his seminal work, terms "mastery experience" - the first-hand experience of success in a given task (i.e. teaching science). Mastery experience is considered to be the primary source of efficacy-building information (Bandura, 1977; Goddard, 2003). Bandura acknowledges that it is actually a combination of mastery experience with other sources of efficacy information (vicarious experience - the observation of a relatable peer achieving success in a task; and social persuasion - the encouragement/feedback from respected mentors) that most effectively builds self-efficacy. Many studies have confirmed this notion both within (Palmer, 2011) and beyond the context of science (Tschannen-Moran, & Woolfolk Hoy, 2007). Whilst vicarious experience and social persuasion can be effectively achieved within the university context, it is only in school settings that first hand science teaching and a sense of mastery experience can be achieved. This makes the need for university-school partnerships within science teacher education paramount for overcoming the prevailing negative outcomes and attitudes that have beleaguered science education for decades.

The essential component of an authentic, school-based science teaching experience for the purposes of gaining mastery experience, raises again the question of how necessary the university might be in the partnership arrangement. It is worthwhile remembering, however, that experts in the field of teacher education argue that it is not experience *per se* that leads to learning, but rather, critical reflection on experience (Loughran, 2002; Korthagen, 2001; Zeichner, 2010). It is this crucial aspect of learning that the teacher educator is best placed to respond to and to provide appropriate experiences. With limitations in primary teachers' background knowledge and ability to teach science, it is also essential that the teacher educator is involved in presenting, modeling and supporting planning for the effective use of science-specific pedagogies and content. With the skill of critical reflection as a core element of teacher development (Zeichner, & Liston, 2014), the importance of the teacher educator to enable this development within the most current theoretical considerations extends beyond science into teacher education more generally.

METHOD

The research study, entitled Science Teacher Education Partnerships with Schools (STEPS), was funded by the Australian federal government's Office for Learning and Teaching. The study adopted a multiple case-study approach commensurate with Yin's (2009) definition of multiple case studies where "the study as a whole covers several [sites] and in this way uses a multiple-case design" (p. 53). This two-year study brought together eight science teacher educators from five Australian universities each representing an individual site. Four of the sites were based in the state of Victoria, and one in Tasmania. The study was limited to the Australian context due to limitations associated with the funding.

Each university involved in the study had independently established some form of a university-school partnership within their science education courses and had conducted various evaluations and improvements to these partnerships over the years they had been functioning. The independent evaluations conducted demonstrated the success of these programs in building pre-service teacher confidence and enhancing attitudes towards science (e.g. see Kenny, 2010; Jones, 2010). The team came together based on their mutual interest and commitment to these practices to identify the similarities and differences between their respective programs, and through a cross-case analysis, aimed to determine the critical features underpinning the success each partnership experienced in its own right.

Data collection and analysis was conducted in three phases, each informing a revision of the dynamic and evolving IF. Each of these phases and subsequent iterations is detailed below.

Phase One: Case studies and literature review

Phase one was an individual case study of each site where the practices and context of each case were identified. A common template was utilized to ensure each case study considered similar areas of information and practice. These areas included the rationale for and goals of the partnership approach; theories informing the teacher educator's practice; the structure of the school-based experience; features and nature of the partnership, including roles of various members; ways in which the children were involved; constraints and barriers encountered; and plans for future practice. This led to a cross-case analysis of the theories underpinning the partnerships through which key themes stemming from the individual cases and ways in which these themes were situated in current literature informing science education and partnerships were identified. This led to the first iteration - the initial drafting of the IF.

Phase Two: Key stakeholders

Phase two of data collection involved key stakeholders within the individual case studies of the programs for the particular year of the study. These stakeholders included pre-service teachers, classroom teachers, principals and course co-ordinators. Pre and post questionnaires were administered to pre-service teachers using Qualtrics software. These questionnaires focused on eliciting changes in attitudes, confidence and background knowledge as a result of the in-schools science-teaching experiences. Ten pre-service teachers also participated in a follow-up interview. Classroom teachers (55), principals (13), course co-ordinators (6), and tutors/lecturers (13) were also interviewed. All interviews focused on how the school-based science program was perceived, its strengths; barriers faced; improvements needed; and its impact as perceived by the different stakeholders.

Quantitative data collected in the questionnaires was analysed for any statistical significant change. Open responses from survey and interview data were programmed into NVIVO and coded according to emergent themes. These analyses informed the next iteration of the IF, where critical practices underpinning the success of the partnerships were framed.

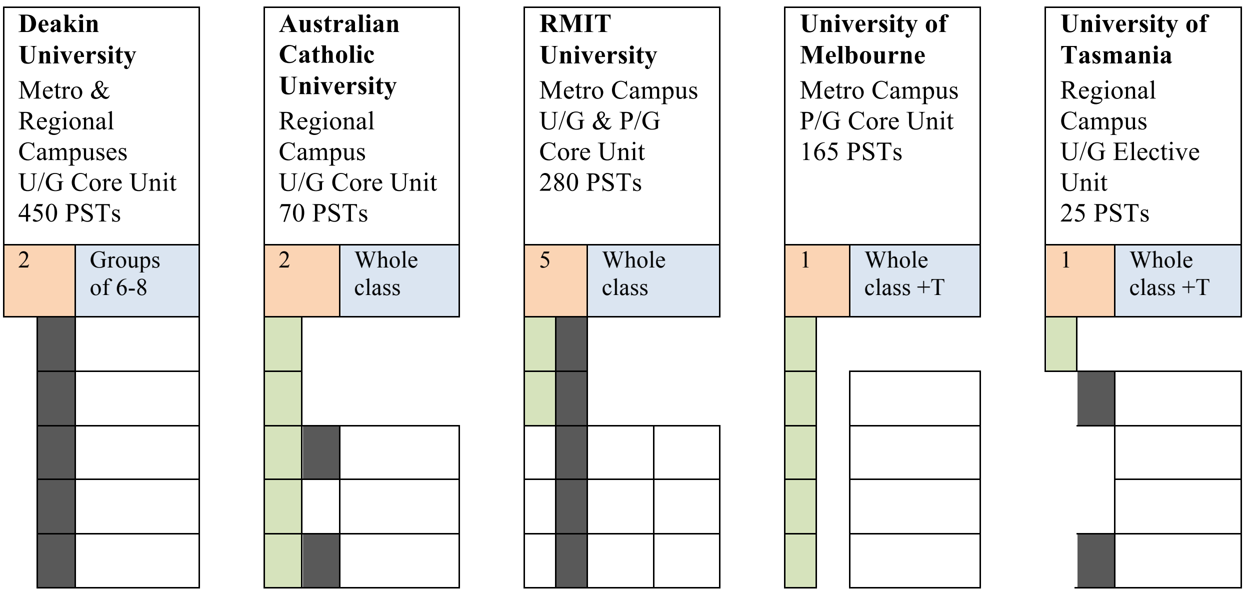
Phase Three: Extending beyond the individual cases

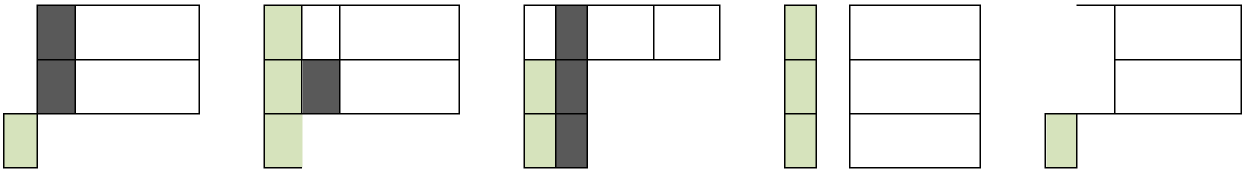
Phase three involved a scoping of partnership practices within science teacher education from other universities around Australia. This resulted in 20 additional interviews. External science teacher educator interviews provided further insights into the features of different partnership practices, including the perceived barriers preventing initiation and/or sustainability.

Together, the three phases of data collection and analysis provided an ongoing, iterative approach to the formation of the IF. At various points throughout the study, the research team, and the reference group advising on the project, reviewed and revised the IF. The IF is presented in this paper in its 13th draft form which has been informed by the rigorous research conducted, as well as feedback from others who have begun to use the IF to form their own partnerships including educators outside of science and industry-based partners.

RESULTS

The results reported in this paper stem predominantly from the case study and the interview data (see STEPS Project, 2015 for findings focused on the questionnaire data). The first iteration of the IF stemmed from the themes identified from the analysis of the individual case studies of each university's program. Figure 1 provides an overview of the diversity of format and structure within the partnerships. For example, individual cases ranged from metropolitan to regional settings; under-graduate to post-graduate courses; pre-service teachers working individually through to small groups of five; pre-service teachers working with small groups of children or whole classes; large cohorts to small; etc. In spite of this diversity the common set of core pedagogies underpinning the teacher educator's practice in establishing their partnership program became evident. Table 1 shows the themes identified in regard to these pedagogies from the individual case templates and interview data, with representative quotes demonstrating the data supporting the identification of each theme.





Organisation of pre-service teachers	Metro: metropolitan city of >100 000 people
Organisation of children, +T = class teacher involvement in teaching	Regional: city/township of < 100 000 people
On-campus classes	U/G: Under Graduate Course
Weeks in which pre-service teachers are teaching	P/G: Post Graduate Course
University tutor in schools	PSTs: Average number of Pre-service teachers

Figure 1. Stucture and Format of Individual Cases

Table 1. Data Representing core themes regarding teacher educator pedagogy

Theme	Exemplary data
Partnership between university & school is fundamental.	Providing PSTs with authentic opportunities to engage school students in science experiences … PSTs worked in teams to design and write a sequence of science lessons *(Teacher Ed*)*
Quality science education.	Inquiry approaches assist the representation of the nature of science so this is of significant emphasis in what I teach in the unit and require the students to apply in their planning and implementation. *(Teacher Ed)*
Schools provide authentic experiences of theory-practice.	It was a fantastic way to integrate the theory and research into best practice science teaching by actually planning, implementing and assessing a science unit within school environments. *(PST*)*
Science teacher educator is an active and supportive member of the partnership.	We also had some power boxes at uni as well and circuits and wires, we had light bulbs as well so all the basic things we needed…liaising with the school, seeing what resources they did have and what sort of resources some schools provide for students in terms of science. *(PST)*
Teaching practice is informed by pedagogical and learning theories.	There was a whole lot of that (theory and practice) because we were pushing the 5E instructional model and the students quickly picked that up and realised that it was a good way to teach, so that bit went in there straight away and the theories behind the assessment theories were put into place fairly quickly. *(PST)*
Children provide authenticity and meaning to help pre-service teachers' learning.	We've learned about the kids' reactions towards science because if we just did this in tutes at uni with uni students you wouldn't get the pure experience of working with kids. You get their true reactions and reflections on things as opposed to just like the theory of someone else had told us how kids would react to things and we actually get to see it for ourselves how they like science or they don't like science. *(PST)*
Pre-service teachers plan, implement and assess a sequence of science lessons.	The most important thing for me and also preparing that lesson seeing all those lessons work so well was the most encouraging part for me and that gave me confidence going into my rounds as well. *(PST)*
Reflective Practice is embedded.	It wasn't until we got back into the tutorials where we could get together to talk with everyone, not just our partner, where we could reflect on what the kids learned, where the learning was going to go, we could use the 5Es to work out where we were going with the next lesson, which was really important. *(PST)*

**PST: Pre-service Teacher; Teacher Ed: Teacher Educator*

Initiating and Maintaining University-School Partnerships

Another key area of data was examined in regards to how the different partnerships were initiated, implemented and sustained over time. This focus led to the identification of a second set of themes that appeared important in the discussion and negotiation processes associated with maintaining the university-school partnerships in the study. Table 2 presents these themes with sample data characterizing each of them.

Table 2. Key Aspects for Consideration in University-School Partnerships

Theme	Representative Data
Aims and Rationale Individual partners think about and communicate their goals for entering the partnership to ensure core needs are addressed in the establishment and implementation of a partnership arrangement.	We hoped that an increase interest in science would result. In the case of the individual teacher – an increased confidence in teaching science in her class. *(Principal)* I wanted my pre-service teachers to have a more authentic experience of teaching science … to plan, implement and reflect on science teaching experiences. *(Teacher Educator)*
Institutional Requirements Partners try to identify the range of requirements and constraints that might impact the partnership and determine the nature of what can be enacted and achieved.	Schools tend to design for a term focus and our university semester cuts across two terms. *(Teacher Educator)* Within the classroom itself we have constraints …you need to have equipment that works and you need to have the knowledge … it's very difficult to find places where I can leave things. *(Classroom Teacher)*
Relationships Building strong relationships is neccessary for success. Communication and time are key requirements to build the sort of trust and respect that underpin a strong, successful relationship.	I think good communication and the opportunity to talk about it first, to say okay. I think there has to be something in it for both of us. *(Classroom Teacher)* It works well because we've had that partnership built up over a number of years so we've got the relationships, the rapport, … they know how we work here, they're familiar with the spaces and the children so that continuity has been really good. *(Classroom Teacher)*
Nature and Quality of Learning Careful planning, including the ways in which subject and general content and pedagogy are implemented, and how reflection is conducted, is required for quality learning for everyone involved.	Through reading the literature I have learnt that you should make sure that you allow adequate thinking time for high-order questions. …Through reflection I have come to realise the importance and place of questioning in the classroom. *(Pre-service Teacher)* The one area that myself am not too keen on is Physics ... This year your students did that with my lot and it was fantastic, I learnt as well. *(Classroom Teacher)*
Commitment to Action A commitment to uphold the agreed-upon roles is important. Partners may re-consider levels of involvement and committment with various iterations of the partnership.	…the school's end they've got to be committed, they've got …(to) want to do it. … the university has to put in place or has to have in place the administrative support. *(Course Coordinator)* I think it's part of our commitment to pre-service teachers, I think it's a quality training ground for them. *(Principal)*

Partnership Typologies

Data also demonstrated that different types of partnerships existed, and that programs were embedded in the schools/universities to differing extents. Table 3 illustrates the three levels of partnership embeddedness identified with examples of data supporting these typologies.

Table 3. Partnership Typologies

Partnership Typology & Description	Representative Data
Connective Partnerships Connective partnerships arise when one or other of the partners has a particular need that the other is able to service. These partnerships sit within existing institutional structures and tend to be "one-off" or short-term in nature; or provide seeding opportunities for other partnerships and/or more long-term partnerships.	It's good for the school, it's nice for us to be able to put in the newsletter that we're in partnership with [the] Uni and there's a science program happening here and we're working with pre-service teachers and that looks good for the school. *(Principal)* A chance to offer (a pre-service teacher) interaction with students in my class. An opportunity to allow my students to do science with someone other than me. *(Classroom Teacher)*
Generative Partnerships New or different practices emerge in school-university programs as a result of generative partnerships. Partners are more responsive to one another's needs and often adjust or develop programs that involve modifications to existing structures to ensure the partnership program can continue.	... it actually excited our staff and got our staff talking and thinking about how we can run science in our school*, (Principal)* Instead of trying to run the whole program myself it gives me a chance to watch and listen to the class and learn about what does and doesn't work. This learning can then be passed onto the uni student along with solutions to help things run smoothly. *(Classroom Teacher)*
Transformative Partnerships Collaboration and active involvement of all partner members in planning and delivery the curriculum for the purpose of joint professional learning are characteristic of Transformative Partnerships. These partnerships are on going and embedded in the programs of the collaborating institutions.	It allowed me to reflect upon my own teaching by observing and assisting. It reinforced just how different children learn and how much they rely on their prior knowledge and experience when completing tasks. *(Classroom Teacher)* …the partnership has been very important for us and it means that we can develop our units with your guidance and that's been a very, very important part of our school and university partnership. *(Principal)*

DISCUSSION AND CONCLUSIONS

The analysis of these three categories of data: teacher educator pedagogies; key elements for consideration in partnerships; and partnership typologies led to the development and refinement of the eventual Interpretive Framework. The IF is a written document in which practice is exemplified, contextualized and summarized. It is presented here in summary format of its four underpinning components: 1) Guiding Pedagogical Principles for Quality and Effective Science Teacher Education; 2) Guide for Growing University School Partnerships [GUSP]; 3) Representations of Partnership Practice [RPP]; 4) Growth Model for Using Partnerships in Teacher Education (see STEPS Project (2015) for more information on the framework and its informing data).

Component 1: Guiding pedagogical principles

The Guiding Pedagogical Principles (Figure 2) emerged as a result of the analysis of data concerned with the teacher educator pedagogies (Table 1). The cross-case analysis of case studies along with supporting evidence from interview data enabled the identification of key practices, theories and beliefs that were both unique and common across the team. These have been summarized in Figure 1 below, and represent the first component of the IF: the Guiding Pedagogical Principals for quality and effective science teacher education. These principles essentially arise from the fact that our practice is embedded in a partnership approach, and would be impossible to achieve without a university-school partnership arrangement of some type.

Guiding Pedagogical Principles

1. Embedded within a partnership between university and schools.
2. A commitment to quality science education.
3. Authentic interaction with children in schools for the purpose of bridging the theory-practice divide
4. Science teacher educator plays an active role in supporting the pre-service teacher in school settings.
5. Science teacher educator and pre-service teacher practice is informed by pedagogical and learning theories.
6. Interaction between pre-service teachers and children is integral to a science-related unit.
7. Involve planning, implementing and assessment of a learning sequence in science.
8. Reflection on and articulation of practice that focuses on pre-service teacher development and identity, and children's learning.

Figure 2. Guiding Pedagogical Principals

The Guiding Pedagogical Principals represent common, core principles that were enabled through the partnership practice undertaken. They also represent the key philosophies underpinning each teacher educator's practice. The commonality of these features across the teacher educators is interesting given that each of the programs was developed independently and had quite distinctive features. This suggests that regardless of the nature, context, and constraints within partnerships, these core pedagogies can be achieved as long as some form of university-school partnership practice is undertaken.

Component 2: Growing University-School Partnerships (GUSP)

Data informing the development the partnerships within this study was reported in Table 2. This data takes into account the perspectives and experiences of different key stakeholders as they reported fundamental aspects that have led to the success and sustainability of their respective partnerships. Emerging from the analysis of this data is The Growing University-School Partnerships (GUSP) component of the IF. The GUSP summarises the five key areas of discussion and negotiation that were identified as crucial for discussion and negotiation. These elements are: A) Aims and Rationale; B) Institutional Requirements; C) Relationships; D) Nature and Quality of Learning; and E) Commitment to Action. The analysis of data showed that these elements can change over time, and are hence are also represented for different stages of a partnership arrangement: 1) as they are initiated; 2) during the period of implementation; and 3) as they are being evaluated. The GUSP (Figure 3) heightens awareness in members of a partnership of the elements they need to consider and/or action through these three stages of working together.

Figure 3. Growing University School Partnerships (GUSP)

	A. Aims and Rationale	B. Institutional Requirements	C. Relationships	D. Nature and Quality of Learning	E. Commitment to Action
Initiation Phase	Identify mutual and differing needs and provide rationale	Identify requirements, constraints and enablers governing the approach to partnership development	Negotiate roles and responsibilities and define value and parameters defining the nature of the partnership	Conceptualise an approach to PST interactions with children	*Initiate contact Negotiate actions (See Partnership Negotiation Tool)*

Implementation Phase	Be mindful of the needs and rationale and be responsive to emerging needs	Manage, compromise, justify and respond to requirements (limitations and possibilities)	Maintain and work with partners to meet individual and differing needs of partners	Enable interactions with children that reflect subject-related and general content and pedagogy	*Monitor and reflect on current levels of commitment and involvement (See Partnership Monitoring Tool)*
Evaluation Phase	Evaluate the needs and rationales for their continued relevance and future possibilities.	Evaluate against institutional requirements, and consider different possibilities & approaches.	Evaluate the nature of the partnership to respond to current and future needs and possibilities.	Evaluate the nature of interactions drawing on a range of evidence, including key stakeholders' reflections and educational research.	*Evaluate commitment and respond with change as necessary (See Partnership Evaluation Tool)*

Component 3: Representations of Partnership Practice (RPP)

A partnership typology, which is connected to the Commitment to Action component of the GUSP, describes the extent to which the partnership informs the planning and practices of the universities and schools involved. In this way, partnership typologies are representative of the level of embeddedness the partnership has in the partnering institutions. The data leading to the identification of each type (Table 3) was synthesised in the analysis, forming the third component of the IF: Representations of Partnership Practice [RPP] (Figure 4). The RPP depicts three levels of partnership embeddedness within the partner organisations: Connective, Generative and Transformative. This typology of partnership practices reflects how ingrained the partnership is within each institution and helps key stakeholders think about the individual roles they would like to take on within the partnership. A range of factors emerged as being central to defining each of these partnership types, and should hence be considered when negotiating the desired outcomes, structures, roles, and levels of responsibility taken on by each partner.

	A. Purposes	B. Institutional structures	C. Nature of partnership	D. Linking theory with practice
Connective	Engagement ased on provision of curriculum or ther service need.	Partnership activities are short-term and opportunistic and sit within existing structure.	Both partners provide short-term services with a focus on one partner's needs but with mutual benefits and value for all.	Both partners recognise schools as important sites for PSTs to link theory and practice.
Generative	Partners recognise opportunities for mutual professional learning	Partnership activities are considered long-term and are planned and catered for in the teacher education and school programs.	Partners jointly plan the structure of the school-based practices to the benefit of both.	Opportunities exist for both partners to reflect on practice that may be linked to theory.
Transformative	Partner involvement based on active professional learning	Partnerships are embedded in the ongoing structures and practices of the institutions.	Partners take joint responsibility for mutually agreed practices and outcomes that are embedded in their respective core outcomes.	Both partners engage explicitly in reflective inquiry guided by theories of professional identity development.

Figure 4. Representations of Partnership Practice (RPP)

The Interpretive Framework as a whole

The three components of the IF emerging from the data reported above have provided key insights into the principles underpinning the partnership practices analysed in this study. Collectively, the guiding pedagogical principals, the GUSP and the RPP have shown that successful partnerships that are carefully constructed and reviewed are not only sustainable over the long term, but enable significant learning and growth in pre-service teachers. This leads to a final component of the IF: Enabling Growth, which we have found to include growth in identify, confidence, praxis and relationships. Aspects of this professional growth were evidenced through the indicators of 1) strengthened identity as a teacher – e.g. "In my first year out I got given science coordinator so I took on a science leadership role" *(pre-service teacher)*; 2) increased confidence through the mastery experiences – e.g. "confidence was the biggest thing and now since I've done it again I've been much more relaxed" *(pre-service teacher)*; 3) enhanced praxis through the expert facilitated reflective practice – e.g. "it was a fantastic way to integrate the theory and research into best practice science teaching by actually planning, implementing and assessing a science unit within school environments" *(pre-service teacher)*; and 4) enhanced relationships between partner members – e.g. "It works very well really and I guess it works well because we've had that partnership built up over a number of years so we've got the relationships" *(classroom teacher)*.

Achieving growth stemmed from the extent of: A) collaboration- e.g. "I actually worked collaboratively with my PLT. There were three other grade five teachers so I worked with them for the brainstorming; if it didn't work you can take it back to uni the next day or the next week and share and having that resource of people" *(pre-service teacher);* B) Communication – e.g. "I think you learn more and more each time about good communication with each other and that helps them and it helps me as well" *(classroom teacher)*; and C) Behaviours and Attitudes – e.g. "I go into teaching I'll know how to do it ... I've delivered a science unit and when I go for a job interview I think confidentially I'd land a successful science job" *(pre-service teacher).* The data demonstrating these enablers and manifestations of growth led to a summary of what we have called the 'Principles of Parntership Practice' (Figure 5).

Principles of Partnership Practice

- Risk-taking and Trust
- Reciprocity and Mutuality
- Recognition of Respective Goals
- Respect
- Adaptable and Responsive
- Diverse Representations

Figure 5. Principles of Partnership Practice

We have found over time that growth in relationships has occured as the communication has improved, and as time has 'proven' the worth and capability of the various arrangements to meet their aims. In the initiation phase, there is an element of risk taken by each partner member, and as everyone commits to the arrangements and success is experienced, the risk-taking and reciprocity between partners grows. This is another reason we believe all of the partnership typologies are beneficial, and hence, are not presented in this paper as a heirarchy, but rather as levels of embeddedness. Many partnerships begin small and grow; others begin and stay small – which is not to say that they are less important, but rather that they are meeting their intended purpose. Thus diversity of partnerships is an important principle to acknowledge. Those partnerships that do grow or change in some way demonstrate the need for adaptability and flexability in the partnership arrangement. This helps partner members respond to emerging issues and ideas to achieve the desired outcomes. Indeed the recogition of partner's respective goals, and openness to how these may change over time, is fundamental to the sustainability of the partnership. The principles of partnership practice and the enablers and manifestations of growth together form the final component of the IF developed in this study. The summary respesentation of the IF is shown in Figure 6. As is the case for this short paper about the framework, Figure 6 only introduces the basic components and summary ideas that emerged from the in-depth analysis of practice from the five universities involved. We hope it is useful in guiding the negotiatin and maintenance of effective and sustainable university-school partnerships for the enhancement of both school learning and teacher education, and refer those interested to the more comprehensive version of the framework (STEPS Project, 2015) in which the components and the 'Action Plan' central to partnership work can be more fully understood and adopted.

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REFERENCES

Bandura, A. (1977). Self-efficacy: Toward a unifying theory of behavioural change. *Psychological Review*, *84*(2), 191-215.

Darling-Hammond, L. (2006). Constructing 21st century teacher education. *Journal of Teacher Education*, *57*(3), 300-314.

Goddard, R. (2003). The impact of schools on teacher beliefs, influence and student achievement: The role of collective efficacy beliefs. In J. Raths & A. McAninch, A. (Eds.), *Teacher beliefs and classroom performance: The impact of teacher education.* Greenwich, Connecticut: Information Age Publishing.

Goodrum, D., Hackling, M., & Rennie, L. (2001). *The status and quality of teaching and learning of science in Australian schools: A research report*. Canberra, Department of Education, Training and Youth Affairs.

Gorodetsky, M., & Barak, J. (2008). The educational-cultural edge: A participative learning environment for co-emergence f personal and institutional growth. *Teaching and Teacher Education, 24*, 1907-1918.

Jones, M. (2010). Collaborative partnerships: A model of professional learning in primary science for practicing and preservice teachers (Unpublished doctoral dissertation). Australian Catholic University, Melbourne. Retrieved from http://dlibrary.acu.edu.au/digitaltheses/public/adt-acuvp299.29062011/

Kenny, J. (2010). Preparing pre-service primary teachers to teach primary science: A partnership-based approach. *International Journal of Science Education, 32*(10), 1267-1288.

Korthagen, F. (2001). *Teacher education: A problematic enterprise in linking practice and theory: The pedagogy of realistic teacher education*. Mahwah, N.J., Lawrence Erlbaum Associates Inc.

Loughran, J. (2002). Effective reflective practice: in search of meaning in learning about teaching. *Journal of Teacher Education*, *53*(1), 33-43.

Palmer, D. (2006). Sources of self-efficacy in a science methods course for primary teacher education students. *Research in Science Education*, *36*, 337-353.

Palmer, D. (2011). Sources of efficacy information in an inservice program for elementary teachers. *Science Education, 95*, 577-600.

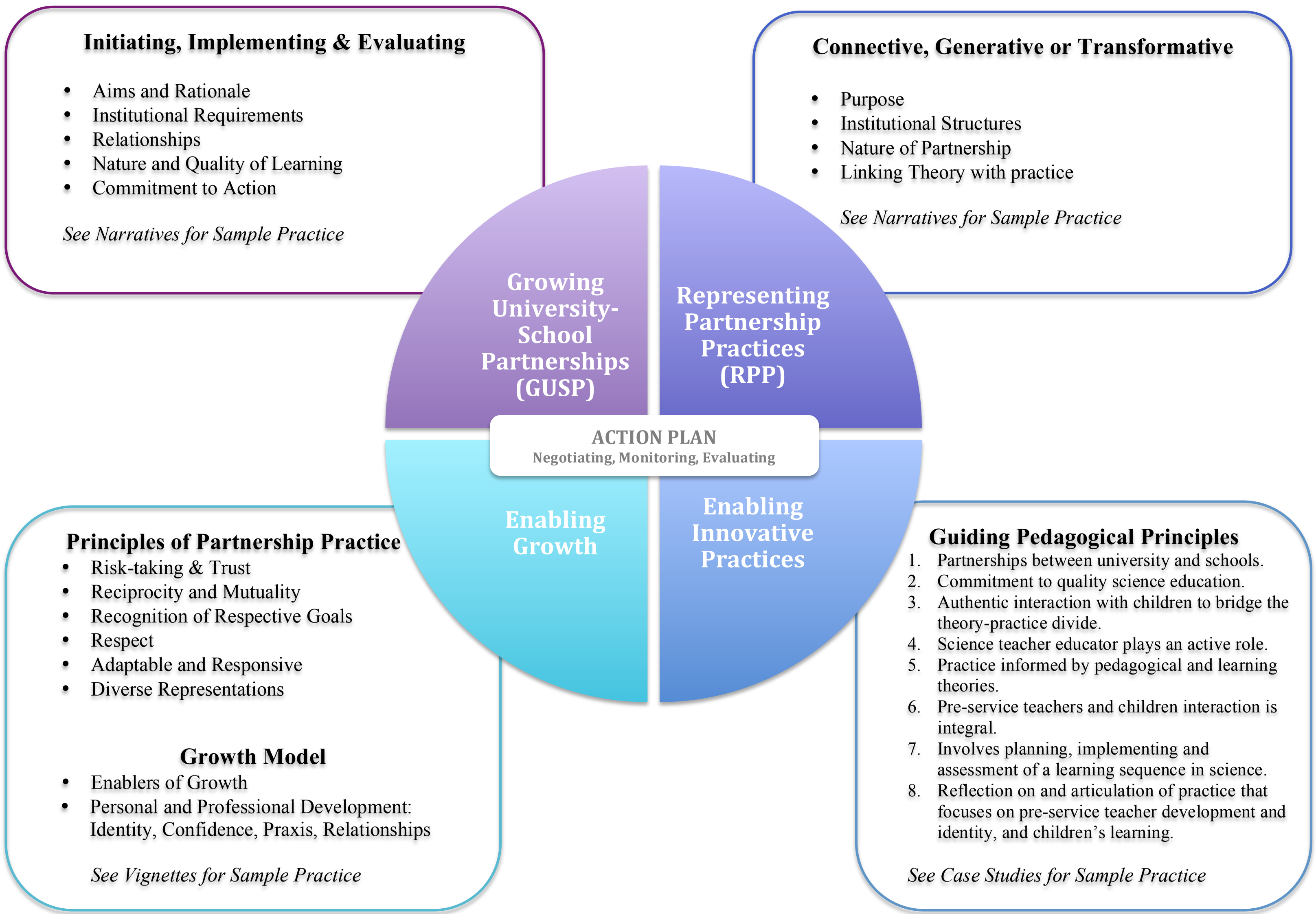
STEPS Project. (2015). *Science Teacher Education Partnerships with School: Interpretive framework*. Retrieved from http://www.stepsproject.org.au/__data/assets/pdf_file/0009/341010/STEPS-Interpretive-Framework-Final-May-2015.pdf

Tschannen-Moran, M., & Woolfolk Hoy, A. (2007). The differential antecedents of self-efficacy beliefs of novice and experienced teachers. *Teaching and Teacher Education, 23*, 944-956.

Yin, R. (2009). *Case study research: Design and methods* (4th ed.). Thousand Oaks, CA: Sage Publications.

Zeichner, K. (2010). Rethinking the connections between campus courses and field experiences in college- and university-based teacher education. *Journal of Teacher Education, 61*(1-2), 89-99.

Zeichner, K., & Liston, D. (2014). *Reflective teaching: An introduction* (2nd ed.). New York, N.Y: Routledge.


Initiating, Implementing & Evaluating
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• Adaptable and Responsive
• Diverse Representations
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• Enablers of Growth
• Personal and Professional Development: Identity, Confidence, Praxis, Relationships
See Vignettes for Sample Practice
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2. Commitment to quality science education.
3. Authentic interaction with children to bridge the theory-practice divide.
4. Science teacher educator plays an active role.
5. Practice informed by pedagogical and learning theories.
6. Pre-service teachers and children interaction is integral.
7. Involves planning, implementing and assessment of a learning sequence in science.
8. Reflection on and articulation of practice that focuses on pre-service teacher development and identity, and children's learning.
See Case Studies for Sample Practice

DESIGNING A COURSE FOR ENHANCING TEACHERS' UNDERSTANDING OF INQUIRY-BASED TEACHING AND LEARNING

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Abstract: The purpose of this study was to investigate the effect of a professional development (PD) program on teachers' development of informed views of teaching science as inquiry. Our approach drew on constructivist learning and situated cognition, built upon nine critical features of effective inquiry PD, and made use of an inquiry-based learning framework reported in the literature. The participants were 72 pre-service elementary teachers enrolled in a science methods course, within which the PD program was implemented. The course was split in 3 phases. During Phase 1, teachers as learners engaged in multiple inquiry-cycles through a designed curriculum in the context of "boiling and peeling eggs". During Phase 2, teachers as thinkers studied the curriculum from its pedagogical rationale, whereas during Phase 3, the teachers as reflective practitioners designed and implemented lesson plans and curriculum materials for the preparation of a student for a science fair project. Content analysis and open coding were used for analyzing the data collected from teachers' definitions of inquiry, reflective diaries, pre-and-post-assessment of teachers' inquiry skills, science fair project work, end-of-course individual interviews. The findings demonstrate that all nine critical features of effective inquiry derived from the literature were addressed in the design and were successfully implemented during the course. Additionally, a significant shift of teachers from naïve to informed views of inquiry was revealed, indicating that the format and structure of the course, in conjunction with the curriculum materials and the teaching approach, significantly influenced prospective teachers' views of teaching science through inquiry.

Keywords: inquiry, professional development, science education

INTRODUCTION

Reform documents in science education have underlined the increasing importance of preparing effective teachers, who will play key roles in guiding students through cognitive activities centered on inquiry (NRC, 2012). Despite this persistent call, most teachers still do not routinely adopt inquiry-based instruction within their practices due to a number of systemic and other barriers. Consequently, current research reports stressed that the key to overcome this gap is to invest on teachers' professional development (PD) both at pre- and in-service level. A critical challenge that emerges is to identify the key features that PD programs should entail in order to succeed in changing teachers' epistemic knowledge of the nature of scientific inquiry, helping teachers appreciate the impact of inquiry-based learning to students' scientific literacy, and assisting them in understanding how to design inquiry-oriented instruction in their classrooms (Capps et al., 2012).

Additionally, it is equivalently important to identify the role of teachers within such a program in order to maximize their professional expertise on teaching science through inquiry. Prior research (e.g., Clarke & Hollingsworth, 2002; Kazempour & Amirshokoohi, 2014; Kerlin, 2012) indicates that positioning teachers in the role of *active learners* rather than as information-gatherers, and letting them experience themselves the same learning journeys that their students are expected to follow, could be beneficial for their professional development, as this role might result in teachers' construction of meaningful knowledge about inquiry and skills for inquiry teaching (Loucks-Horsley et al., 1998). A second role that is important for teachers to encounter during their participation in a PD program is the role of *thinkers* of both the learning experiences gained through the inquiry hands-on activities and the underlying design principles of the curriculum materials they engaged with as learners. Theoretical readings, class discussions, and other reflective activities may facilitate this role of teachers, as they allow them to reflect on their developing understandings, enhance their knowledge about certain aspects of inquiry-based learning, and can shed light on prior established misconceptions about inquiry and science in general (Akerson et al., 2007). Lastly, given that reflective practice, which refers to the capacity to reflect on action that leads in engagement in a process of continuous learning (Schön, 1983), can be a beneficial form of teachers' professional development (Ferraro, 2010), a third role that is considered essential for teachers to follow during attending a PD program is that of *reflective practitioner*. This role is facilitated through allowing teachers to implement curriculum materials they developed or received within the context of a PD program into their own practice, make necessary adjustments to their teaching according to situations occurred at particular time, collect evidence to evaluate and reflect on the effectiveness of their teaching, and bring reports of their field experiences to the course and analyze teaching strategies with their mentors and colleagues.

PURPOSE AND RESEARCH QUESTIONS

We present the structure of a PD program through which we aimed to impact on teachers' development of informed views of inquiry and teaching science as inquiry. Our approach draws on the constructs of constructivist learning (Driver et al.,1994) and situated cognition (Brown & Campione,1990) and builds upon nine critical features of effective inquiry PD suggested by Capps et al.(2012)(Table 1). The development of the curriculum materials incorporated within the course was grounded on the inquiry-based learning framework suggested by Pedaste et al. (2015).

The research questions that we aimed to address in our study are as follows:

(1)To what extent is the PD program aligned with the nine critical features of effective PD as suggested by Capps et al.?
(2)How did teachers' views of inquiry and teaching science as inquiry change along the course?

METHODOLOGY

The participants were 72 pre-service elementary teachers who attended a science methods course, within which the PD program was implemented. During the previous semester, all teachers attended a content course that made use of the Physics by Inquiry curriculum (McDermott et al, 1996), whereas none of them taught science during their school practicum.

The PD course, taught by 2 university instructors and 3 graduate assistants, was organized into twelve 1,5-hour sessions and split in 3 phases. During Phase 1, a curriculum titled "Boiling and Peeling Eggs" was implemented, through which the participants/teachers (groups of 4) engaged in multiple inquiry-cycles to answer "How to make perfect hard boiled eggs that are ease to peel?". Specifically, the teachers as *learners* defined the problem that merited solution, identified variables that might affect the boiling and peeling of eggs, formulated investigative questions and hypotheses, designed and performed experiments, collected, analyzed, and interpreted data, drew conclusions and represented their findings in posters. During Phase 2,the teachers as *thinkers* were asked to study the curriculum they previously worked with to identify the phases of inquiry and their interconnections, in order to inductively formulate the underpinnings of the inquiry-based framework that guided the design of the curriculum. Next, the inquiry-based framework was introduced and the teachers compared their perceived frameworks with the original one. Finally, during Phase 3, the teachers were assigned the role of *reflective practitioners* and were asked to design lesson plans and curriculum materials on a particular topic that would use to engage an elementary student in inquiry-based activities. Throughout the meeting with their student, the teachers maintained reflective journals to record their student's inquiry-based learning progress and all phases of inquiry were reported on a poster that was presented during a *Science Fair* organized in collaboration with the participants/teachers and a local school.

We collected multiple forms of data: (a)*Participant observations*; (b)*Teachers' written definitions of inquiry*, as documented in questionnaires administered during the first, the seventh and last course meeting; (c)*Reflective diaries*, in which teachers were asked to document their evolving understanding of inquiry-based learning; (d) *Pre- and Post-assessment of teachers' inquiry skills*; (e)*Science fair project work*; and (e)*End-of-course individual interviews*.

To answer the first question, content analysis (Elo & Kyngäs, 2007) of the developed curriculum materials was used, whereas an open coding scheme refined through the use of the constant comparative method (Glaser & Strauss, 1967) was followed for answering the second question.

FINDINGS

The content analysis of the curriculum materials developed for the purposes of the PD program revealed that all nine critical features of effective inquiry suggested by Capps et al. (2012) were addressed in the design and implementation of the PD program. Table 1 entails relevant information to support this finding.

As far as the second question is concerned, the findings revealed that all teachers held uninformed views of inquiry and teaching science as inquiry in the beginning of the course. This finding emerged from the analysis of their definitions of inquiry, the descriptions of lessons centered on inquiry, the articulation of inquiry skills and knowledge that learners develop during inquiry, and the teaching skills to teach science as inquiry. At the end of the course, the majority of teachers transitioned to more informed views of inquiry and teaching science as inquiry. Representative quotes from a teacher's responses in the various means of data collected are presented in Table 2.

DISCUSSION AND CONCLUSIONS

The purpose of this study was to investigate the effect of a professional development (PD) program on teachers' development of informed views of teaching science as inquiry. The findings demonstrate that all *nine critical features of effective inquiry* derived from the literature were addressed in the design and were successfully implemented during the course. Given that the reviewed empirical studies reported by Capps et al. (2012) failed to meet all nine recommended features in unison, this finding is promising in that the PD program of this study appears as an exemplary one that took into consideration all nine features that are critical for the design and implementation of PD programs centered on inquiry.

Additionally, a significant shift of teachers from naïve to informed views of inquiry and inquiry-based teaching was revealed, indicating that the format and structure of the course, in conjunction with the curriculum materials and the teaching approach, significantly influenced prospective teachers' views of teaching science through inquiry. This finding indicates that engaging teachers as *learners*, *thinkers*, and *reflective practitioners* in a strategically designed PD program can create a gestalt shift in their philosophy of how to teach science as inquiry.

Table 1. Illustration of evidence to document how the critical features of effective inquiry suggested by Capps et al. (2012) were addressed in the design and implementation of the PD program

Features		How critical features of effective inquiry were addressed in the PD program of the study?	Frequency of occurrence in the 17 papers reviewed by Capps et al.
Structural features	Total time	10 weeks – in-course (*teachers as learners and as thinkers*): 6 weeks: 12 x 1,5 hour sessions; beyond-course (*teachers as reflective practitioners*): 4 weeks: 8-10 2 hour meetings with their students	From 1 to 6 weeks
	Extended support	During Phase 3 (*teachers as reflective practitioners*), the teachers received feedback on their science fair project proposals by the instructors of the course. They also met with the instructors once a week on a volunteer basis to pose questions, discuss problems encountered during the meetings with their students, and get support on their future steps. The support received was also extended and enhanced via online communication; a social network page was created to offer teachers the opportunity to exchange ideas with their peers, share learning experiences and lessons learned from the meetings with their students, and also to receive feedback on their lesson plans and curriculum materials from the science teachers of the local school that their students came from.	13 out of 17
	Authentic experience	During Phase 1 (*teachers as learners*), the teachers were engaged with a curriculum developed for the purposes of this course titled “Boiling and Peeling Eggs” and they were prompted to answer “How to make perfect hard boiled eggs that are ease to peel?” Specifically, the teachers (working in groups of 4) defined the problem that merited solution, identified variables that might affect the boiling and peeling of eggs, formulated investigative questions and hypotheses, designed and performed valid experiments to answer their questions and test their hypotheses, collected, analyzed, and interpreted data derived from their experiments, drew conclusions from the data and represented their findings in posters to communicate with the rest of their peers. They neither received lecturing on what inquiry is and how it is performed, nor were given ready-made experiments to follow in answering their questions. Instead, they worked in the science lab for an extended amount of time aiming to produce reliable knowledge on the topic of boiling and peeling eggs that could not be found in books, the internet, etc.	5 out of 17

Table 1. Illustration of evidence to document how the critical features of effective inquiry suggested by Capps et al. (2012) were addressed in the design and implementation of the PD program

Features		How critical features of effective inquiry were addressed in the PD program of the study?	Frequency of occurrence in the 17 papers reviewed by Capps et al.
Core features	Coherence	Inquiry-based learning is manifested in the national curriculum of the country and the science textbooks' units are considered to have been developed on the tenets of the inquiry-based approach. Thus, the compatibility and coherence of the aims and content of the course with the national curriculum was believed to facilitate and support teachers' teaching practice when entering the school for the purposes of their school practicum the following academic year.	all 17
	Developed lessons	During Phase 3 (*teachers as reflective practitioners*), the teachers were asked to developed lesson plans and curriculum materials that would use in engaging a student in inquiry-based activities for the purposes of the Science Fair project. In developing their lesson plans, the teachers formulated learning objectives and designed activities that were aligned with the principles of inquiry-based learning (e.g., students would learn how to formulate investigative questions, test hypotheses, develop and apply the control of variables skill, design and perform controlled experiments, make inferences from the data collected, use evidence to develop explanations, etc.).	7 out of 17
	Modeled inquiry	The participating teachers (working in groups of 4) were assigned to the role of *learners* during Phase 1 of the course and followed the specially designed curriculum to complete activities and evaluation tasks in an attempt to learn first-hand how inquiry-based learning looks like in the curriculum. The teachers discussed the progress of their work with the course instructors during "check-out points" placed in specific stages of the curriculum. The instructors aimed to engage teachers in *semi-socratic* dialogues during the checkout points, instead of merely answering questions or providing the correct answers to the activities of the curriculum. Both the format of the curriculum, the structure of the course, and the role of the instructors aimed to help teachers in visualizing how inquiry-based instruction looks like and thus it was anticipated that they would appear more ready and confident in their own field of practice for scaffolding their pupils' learning pathways while involved in inquiry-based activities.	16 out of 17
	Reflect	During Phase 1 (teachers as *learners*), the teachers were asked to keep reflective diaries to record their evolved understandings of inquiry, the questions and problems that emerged during working with the curriculum to answer the investigative questions they formulated, and their impressions from the course. Also, during positioning teachers as *thinkers* (Phase 2) they were asked to reflect on the curriculum they were engaged in the previous stage as learners from the lens of its pedagogical rationale, and discuss how inquiry skills and knowledge were fostered within specific learning activities.	15 out of 17
	Transferen ce	Teachers adapted the format and structure of the curriculum they were engaged with, during Phase 1, in order to design their own curriculum that would use during the engagement of an elementary school student in inquiry-based activities for the purposes of the Science Fair. During designing their curriculum materials, they received feedback from the instructors on certain aspects of their work, which was proven beneficiary in transferring the PD materials and experiences in their own field of practice.	15 out of 17
	Content knowledge	The course not only focused in engaging teachers in inquiry-based activities, but also on helping teachers develop specific content knowledge, including understanding of certain aspects of the nature of science, the nature of scientific inquiry, and the science concepts that related to the context of the curriculum (e.g., boiling, heat and temperature, egg protein denaturation, etc). Additionally, the course gave emphasis on promoting teachers' development of inquiry skills like control of variables, design of controlled experiments, data interpretation and inference drawing, etc.	11 out of 17

Table 2. Quotes from a teacher’s responses in various assessment tasks that illustrate the transition from naïve to informed views of teaching science as inquiry

Inquiry aspects	Prior to the course	After the course
Definition of inquiry	*“Inquiry is a learning situation during which students and teacher interact, discuss, and experiment with an appropriate problem and at the end they reach at a mutual response.”*	*“Inquiry is a process, similar to the one scientists follow in their daily work, though which a learner engages with a problem and performs several actions for solving the problem. Inquiry involves defining the problem of interest, making some research on getting insight on the concepts that relate to the problem, formulating a question and generating a hypothesis based on the question, designing a controlled experiment to answer the question, collecting and interpreting data, and drawing conclusions in relation to the initial question. The process is not a linear one, since one can follow different paths depending on the type of problem, the conceptualization of the problem, etc., and you can always go back to further investigate your question or formulate and test new research questions.”*
Description of a lesson centered on inquiry	*“The objective of a lesson is students to get familiar with the magnets, and especially with their poles. Initially, the teacher problematizes his students, and then students experiment and test their hypotheses. The teacher does not provide ready-made responses, but evaluates students through appropriate questions.”*	*“The teacher introduces students to a problem that relates to why some objects sink and some others float in water. She prompts students to pose their initial ideas (these might relate to the identification of variables that might affect the sinking/floating of objects), and helps students to formulate hypotheses that would later test through experiments. Before formulating hypotheses, the students formulate investigative questions in the form “Does variable A affect variable B?”, and for each question they formulate a hypothesis. Next, the students are asked to choose a question and design a controlled experiment (only one variable is altered while the rest are maintained constant) for answering it. During their experiment, they collect data, organize them in a table, and when they have collected enough data, they proceed in interpreting their data in relation to their initial hypothesis and investigative question. The students follow the same procedure for answering all investigative questions, and the support from the teacher faints out, as she observes that the students are able to transfer the experimental design strategy for investigating the effect of new variables in the sinking/floating of objects”.*
Inquiry skills a student should master in order to engage in inquiry	*“It is essential that students should be able to collaborate with each other and follow specific instructions. Also, it is important that students are not used of receiving ready-made knowledge, but be able to formulate conclusions themselves”.*	*“A student should have mastered several inquiry skills in order to enroll in inquiry activities. These skills are as follows: (i) identification of variables skill; (ii) formulation of investigative questions skill; (iii) control of variables skill; (iv) data interpretation skill; (v) hypothesis generation skill; (vi) hypothesis testing skill”.*
Assessment of students’ inquiry competence	*“During the first lesson with electric circuits, I would ask students to form groups of four and then I would give them a wire, a light bulb and a battery and I would challenge them to find a way to make the bulb to lit. Hence, I would be able to observe their reactions, if they are able to collaborate with each other, and with appropriate guidance I would keep notes if they can learn something new by themselves”.*	*“I would ask students to describe what they should do if they wanted to learn whether the sun is essential for plants to growth. In scaffolding their work, I would present 6 different pictures that varied in the type of the plant, the size of the pot, the presence/absence of sun, and the amount of water that is added in each pot, and I would ask them to choose which two they should choose in answering the posed question”.*

REFERENCES

Akerson, V. L., Hanson, D. L., & Cullen, T. A. (2007). The influence of guided inquiry and explicit instruction on K-6 teachers' views of nature of science. Journal of Science Teacher Education, 18, 751–772.

Brown, A.L., & Campione, J.C. (1990). Communities of learning and thinking, or a context by any other name. In D. Kuhn (Ed.), *Developmental perspectives on teaching and learning thinking skills* (Vol. 21, pp. 108–126).

Capps, D., Crawford, B, & Constas, M.(2012). A review of empirical literature on inquiry professional development. *J Sci Teacher Educ*, *23,* 291-318.

Clarke, D., & Hollingsworth, H. (2002). Elaborating a model of teacher professional growth. *Teaching and Teacher Education*, *18,* 947–967.

Driver, R., Asoko, H., Leach, J., Mortimer, E., & Scott, P. (1994). Con- structing scientific knowledge in the classroom. *Educational Re- searcher*, *23*(7), 5–12.

Elo, S.& Kyngäs, H.(2007).The qualitative content analysis process. *J.ofAdvNursing*, *62*(1), 107-115.

Ferraro, J. M. (2010). Reflective practice and professional development. ERIC Digest: Retrieved from http://www.eric.ed.gov/PDFS/ED449120.pdf.

Glaser, B., & Strauss, A. (1967). *The discovery of grounded theory*.New York: AldinedeGruyter.

(NRC). 2012. *A framework for K–12 science education: Practices, crosscutting concepts, and core ideas*. Washington, DC: National Academies Press.

Kazempour M., & Amirshokoohi A. (2014). Transitioning to Inquiry-Based Teaching: Exploring Science Teachers' Professional Development Experiences. *International Journal Of Environmental & Science, 6*(3):285-309.

Loucks-Horsley, S., Hewson, P. W., Love, N., & Stiles, K. E. (1998). Designing professional development for teachers of science and mathematics. Thousand Oaks, CA: Corwin Press, Inc.

Pedaste, M., et al. (2015). Phases of inquiry-based learning: definitions and inquiry cycle. *EducationalResearchReview*.

Schön, D. (1983) *The Reflective Practitioner. How professionals think in action*, London: Temple Smith.

INVESTIGATING THE RELATION BETWEEN DECLARATIVE AND PROCEDURAL PRE-SERVICE CHEMISTRY TEACHERS' KNOWLEDGE ABOUT ANALOGIES

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Abstract: In this paper, we investigate the ideas that pre-service chemistry teachers stated about analogies (declarative knowledge) and their relation to the process of elaborating their own analogies (procedural knowledge) using to facilitate elementary and high school students' understanding of the topic chemical reactions. Our sample was made up of 14 pre-service chemistry teachers studying in different semesters of the course. The data were obtained through a questionnaire and validated through interviews with the respondents. Such data supports our discussions about interrelationships between what the pre-service chemistry teachers affirmed they knew about analogies and the way they used their procedural knowledge to generate analogies. The analysis of the data supports the conclusion that focusing teachers' training courses exclusively on declarative knowledge about analogies does not seem sufficient to support them in elaborating good analogies. From this, we discuss implications for educating future teachers from more authentic conceptions about analogies.

Keywords: analogy, teachers' education, declarative knowledge, procedural knowledge

INTRODUCTION

An analogy is a comparison in which relations between a familiar domain – the *analogue* – and an unknown domain or one that is not very familiar – the *target* (Gentner, 1989) are established. Therefore it has been recognised as a reasoning tool, which is potentially useful.

This support for reasoning and other diverse purposes for using analogies (such as in problem solving, developing mental models, communicating ideas, generating hypothesis, etc.) explain why they are so widely used by scientists (Clement, 2008; Gentner, 1989; Nersessian, 1992) and in science teaching (Aubusson, Harrison, & Ritchie, 2006; Harrison & Coll, 2008).

Despite this, very little has already been investigated about the understanding and use of these tools by future science teachers. In order to try to bring together the current literature and to open up prospects for more successful teacher training in this area, in this study we investigate the ideas that pre-service chemistry teachers express about analogies, and we establish relations between such ideas and the analogies they generated.

Analogies in Science and in Teaching Science

Analogical reasoning, as a human thinking resource, assists and/or promotes discovery and creativity of scientists when building science. Scientists make use of analogies for different purposes: in solving problems; in developing their mental models; in attempts to explain abstract concepts; in communicating ideas and convincing a certain group about their validity; in generating hypothesis; in designing experiments; in an attempt to solve the problems found in these experiments (Coll, 2005; Dunbar, 2000; Dunbar & Blanchette, 2001; Nersessian, 1992). Perhaps due to all these purposes, the physicist Robert Oppenheimer (1955) recognised that "(...) *analogy is indeed an indispensable and inevitable tool for scientific progress*" (p. 129).

A detailed example of drawing analogies, which also comes from the domain of physics, is given by Nersessian and her collaborators (see Davies, Nersessian, & Goel, 2005; Nersessian, 1999). In these studies, the authors explain how Maxwell produced a visual model of an "electromagnetic field" from building analogies, and conducted several tests to improve their scope and predictive power. Nersessian (1999) also comments about the use of models and analogies by Maxwell with the purpose of communicating the knowledge he had created and in an attempt to convince other scientists of its potential.

This example clearly demonstrates the importance of the use of analogies by scientists to the advance of scientific knowledge. Considering the roles played by analogies in science previously mentioned, it emerges the importance of promoting the use of analogical reasoning in the teaching and learning of science (Aubusson et al., 2006; Clement, 2008; Vosniadou, 1989).

The possible educational benefits of analogies have been widely discussed in science teaching literature. In general, it is recognised is that they can: facilitate understanding and/or visualization of abstract content; motivate the students interest; facilitate access to prior knowledge and/or the students alternative conceptions; give support to predictions in relation to some aspects of the target domain; present *creative function*, i.e., help to discover new problems and generate hypothesis for their solutions; become an important cognitive mechanism for acquiring new knowledge and/or promoting changes in the students representations of the target domain; develop a more reliable conception of scientific work; develop a metacognitive awareness in the students, among other benefits (for example: Coll, 2005; Duit, 1991; Glynn, Britton, Semrud-Clikeman, & Muth, 1989; Vosniadou, 1989).

Despite all of these potential benefits, most of the times analogies are used in teaching science, the analogue and the target domains are given by the teacher and it is expected that the students establish the relations between the domains that would help them to produce an expected mental representation of the target domain. Blanchette and Dunbar (2000) associate such use of analogies to a *reception paradigm*. Yet, this objective is not always attained as the students knowledge base may be different from that through which teachers and scientists establish analogical relations when elaborating their analogies (Wilbers & Duit, 2006).

On the other hand, the drawing of analogies by the students themselves is related to the *production paradigm* (Blanchette & Dunbar, 2000), which has been pointed out by few studies (Clement, 2008; Mozzer & Justi, 2012; Pittman, 1999; Wong, 1993) as a more effective activity. This is because, in providing students with the opportunity to establish their own analogies, they have to look for relations of similarity from their own perspective, which may lead them to a deeper understanding of the compared domains (Pittman, 1999). Studies such as the one done by Wong (1993) provide us with empirical support to the idea that involving students in the process of elaborating their own analogies may stimulate them to generate new inferences and insights.

Unfortunately, the drawing of analogies by students is an uncommon activity in the context of the science classrooms. Perhaps this is also the main reason for which pre-service teachers, who are trained according to the reception paradigm, have difficulties in using analogies creatively during and after their educational training, as shown in the subsequent section.

Use and Drawing of Analogies by Science Teachers

By moving the focus of the discussion to the use and drawing of analogies by science teachers, the situation has not shown itself to be less problematic than that of the students. Studies have shown that, in general, science teachers: do not have a well prepared, valid repertoire of analogies, draw them without the necessary attention, at the time they are teaching in the classroom; offer students little or no clarification about the metaphoric aspects of the anthropomorphic language used in the comparisons; expect students to understand the analogical relations, which present a clear and objective meaning to them, but not necessarily to their students; prefer to draw analogies with topics or experiences that are part of the students everyday life, but are not structurally similar to the target domain (i.e., make mere appearance comparisons); tend to confuse analogies with other teaching tools, as shown in Duit (1991); Mozzer and Justi (2013); Treagust, Duit and Joslin (1992); Wilbers and Duit (2006).

Science teachers also seem to be unaware of analogical reasoning, of the importance of identifying where analogies break down (Mozzer & Justi, 2013), and frequently, do not make the mapping between the compared domains explicit to their students (Dagher, 1995). Additionally, it is common that future teachers had developed inadequate conceptions about the nature of science during their secondary and university education. The views of science as an empirically obtained collection of facts, and as something absolute, as well as an underestimate of imagination and creativity in the production of knowledge are some of the effects of inadequate conceptions about the nature of science (Lederman & Gess-Newsome, 1999), which can also influence future teachers conceptions about analogies.

Gess-Newsome (2003) stress that changes in teachers' knowledge can take place when they are exposed to new ideas and experiences; when they use a given knowledge; and when they actively reflect about such knowledge. However, given the research evidence and theoretical points emphasised in this section, it seems that future teachers have not been provided with support that could contribute to make them able to build a strong and proper knowledge about analogies.

In order to plan and design changes in science teachers' knowledge about analogies, more information is needed about the construction of knowledge by future teachers. This would allow us to establish relations between what they express (*declarative knowledge*[1]) about ideas to which they are presented to during their training courses, and the manner in which they use them (*procedural knowledge*[2]).

Wherefore, in this study, we investigate the following research questions:

- Which ideas do pre-service chemistry teachers express about analogies?
- What relations can we establish between their declarative knowledge about analogies and the analogies that they drawn (procedural knowledge)?

A discussion of these questions aims at bringing together knowledge from distinct areas and paving the way for more helpful teacher training in this area.

METHODOLOGY

Our sample was made up of 14 Brazilian pre-service chemistry teachers, studying in different semesters of their university education. Three of them were in the fifth semester, in which the first discussions about analogies take place; eleven were in their seventh semester and, as such, had already experienced discussions about analogies.

In order to reach the aims of investigating how pre-service chemistry teachers understand analogies and the relation between this knowledge and the comparisons they made, they completed a written questionnaire. The questions were focused on their understanding concerning: the concept of analogies; the drawing and use of analogies by scientists; the teachers aims when drawing and using analogies; the differences between analogies and other comparisons; the basic characteristics of a good analogy to be used in science teaching; the drawing of an analogy to facilitate students understanding of chemical reactions.

In analysing the data, categories were created based on the main focus of each question, and subcategories were developed based on ideas found in the pre-service teachers' answers. When identifying the type of comparison drawn by the subject, we tried to evaluate if he/she had established relations between the domains (which characterises an analogy), only compared features of the object or descriptive aspects, such as colour, size, shape, etc. (which characterises a mere appearance comparison) or both (which characterises literal similarity). This was done even though the pre-service chemistry teachers had not explicitly expressed the correspondences between the domains.

In order to validate the inferences made by the researchers, a semi-structured interview was carried out. The pre-service chemistry teachers were asked to: (i) make a critical analysis of the analogy drawn; (ii) map the analogy explicitly (ii) make an analysis of the inferences and considerations brought out by the researcher about the analogy in question.

In this study, we exemplified the analysis of two cases: that of L2 (a pre-service teacher coursing the 5th semester) and that of L4 (a pre-service teacher coursing the 7th semester), whose ideas about analogies were compared whenever possible.

RESULTS

In table 1, the pre-service chemistry teachers' ideas about analogies are presented according to the categories and subcategories defined from the questions. In tables 2 and 3, the respective mappings established by the pre-service teachers and/or inferred by the researchers (these are represented in brackets) are presented. In these tables, a solid double arrow represents relational mapping, while a broken double arrow represents mapping of objects' attributes.

Table 1. Categories and subcategories representing the pre-service chemistry teachers' main ideas about analogies.

Category	Subcategory	Pre-service chemistry teacher	Examples of answer
Definition of analogy	Explanatory tool for comparing distinct domains	L2	"*It is something used for comparing different concepts, to improve the understanding of one of these concepts.*"
	Explanatory tool for establishing explicit relations between the target and the analogue	L4	"*It is an instrument which can help us explain something unknown to the students, making them able to understand something unknown (target domain) from the establishment of a relation (mapping) with something known to them (analogue domain).*"
Scientists' aims for using analogies	To facilitate other people's understanding	L2, L4	"*To improve understanding and accessibility of concepts. It would be a way of giving a better explanation with simpler concepts.*" (L2)
Teachers' aims for using analogies	To facilitate the understanding of something unknown from something known	L2, L4	"*If the mapping is done, it can support the students understanding of something to be explained from something which is already known to the students.*" (L4)
Difference between analogies and other comparisons	Comparisons between scientific knowledge and something known *versus* everyday comparisons	L2	"*Analogies are comparisons of a scientific nature with other things; they are not, for example, mere comparisons between one thing and another.*"
	Deep relations *versus* appearance correspondences	L4	"*An analogy is a comparison in which relations are established. However there are comparisons in which the established correspondences are only of appearance.*"

Table 1. Categories and subcategories representing the pre-service chemistry teachers' main ideas about analogies (continuation).

Category	Subcategory	Pre-service chemistry teacher	Examples of answer
Types of comparisons made	**Potential analogy**	L2	"*The toy 'come and go'*[3] *could be an analogy in relation to the "vice versa movement" of the reaction in equilibrium: at one time it favours the formation of products, then at another time it favours the formation of reagents.*"
	Mere appearance comparison	L4	"*When we have a man and a woman and they "generate" a child, we can also think about chemical reactions, in the end we don't have the same thing as we had in the beginning. In the case of the analogy, initially we have one man and one woman generating a child, whilst in the case of reactions we have reagents forming the products. In the reactions, there are no relations of feelings and the reagents and the products do not have life.*"
Ideas expressed from the comparisons	Analogies break down	L4	"*In reactions there are no relations of feelings and the reagents and products do not have life.*" (L4 points out where his comparison breaks down).
The characteristics of a good analogy in science teaching	To have a well defined aim	L2	"*It really has to have a link with the subject matter, goal, function and it has to support the explanation of the concept.*"
	To allow the making of relations with the target domain	L2, L4	"*There should be relations to what you wish to explain.*" (L4)
	To make reality closer or intelligible to students	L4	"*It* (the analogue) *should be something the students are aware of.*"

Figure 1. "Come and Go" toy. (Available from: velhariadigital.wordpress.com/2012/09/23/vai-vem-trabalhando-biceps-desde-os-anos-70. Access: 05/01/2015)

Table 2. Comparison made by L2 between the toy "come and go" and reversible reactions.

Target (Reversible reactions)	Mapping	Analogue (Toy "come and go")
A chemical reaction may occur both in the sense of forming products, and forming reagents.	⟷	"The ball can move in the direction of the reagents as well as in the direction of the products."
[During the state of equilibrium, the rate of the direct and inverse reactions is equal and the formation of neither species prevails.]	⟷	If both players use equal force, the ball will stay in the middle and neither direction of displacement will prevail.

Table 3. Comparison made by L4 between having a child and chemical reactions.

Target (Chemical reactions)	Mapping	Analogue (Having a child)
In chemical reactions, reagents combine to form a product.	⟷	The relation between a man and a woman results in a child.
The product is different from the reagents.	⟷	The child is different from the man and the woman.

DISCUSSION AND CONCLUSIONS

An analysis of table 1 allowed us to ascertain that although L2 and L4 conceived analogies as explicative tools, L2 conceived them in a generic manner, as a comparison of two different domains. For him, any kind of comparison between different domains aiming at explaining something could be classified as an analogy, independently of the nature of the mapping relationships established between such domains. However, L4 was able to specify essential attributes that characterise analogies and differentiate them from other types of comparisons, like the relational nature of the mapping and the explicit expression of such relations.

Both L2 and L4 identified and discussed the explicative function of analogies, but they were not able to identify other functions for analogies, like their role in supporting reasoning, interpretation of ideas or phenomena, and visualisation of abstract domains. This seems to reflect their views about the aims of using and generating analogies in science and science teaching, since L2 and L4 expressed only their role in facilitating understanding.

The way in which L4 conceived analogies may have been the determinate factor for him pointing out the characteristics of a good analogy for teaching: the possibility of mapping relations between the analogue and the target and the necessity that students were familiar with the analogue. From such characteristics, he differentiated the analogies from the other comparisons by emphasising the deep relations that analogies allow to do (contrary to other comparisons). On the other hand, L2 showed only the need to keep in mind the aim of the analogy and its capability of explaining scientific knowledge (unlike other comparisons).

Such results supports our hypothesis that, due to his weak understanding about the meaning of analogies, L2 were not able to mention the most relevant and specific attributes of a good analogy to be used in science teaching, as L4 did.

From the points discussed up to now, we may say that L4 showed a more accurate declarative knowledge about analogies than L2. This was so because L4 was able to mention and discuss core attributes that characterise analogies and differentiate them from other comparisons, whilst L2 pointed out only less relevant attributes, or those that are valid for other comparisons. Although L4 had expressed a significant declarative knowledge, neither he nor L4 emphasised the importance of identifying and discussing the limitations of an analogy. In science teaching context, the absence of discussions about the limitations of analogies may generate, or reinforce, students' misunderstanding about scientific representations being always correct, i.e., being able to represent all attributes of the represented entity (Harrison & Coll, 2008).

Yet, when they were asked to draw an analogy (that is, to express procedural knowledge), L2 was able to draw what we called a "potential analogy" and to identify where his analogy "breaks down" – aspects that could not be mapped between the analogue and the target – (see table 2). This occurred despite he had not experienced formal discussions about analogies, as L4 had. We called his comparison a "potential analogy" because although he had not explained the mappings, these were likely to be relational. Additionally, although L2 had not expressed a proper declarative knowledge about analogies, he showed to have some of the relevant skills necessary to draw them, like imagination, creativity, and abstract reasoning.

On the other hand, although L4 was able to identify relevant characteristics of a good analogy for teaching, and had clearly differentiated them from other comparisons, he made a mere appearance comparison (see table 3).

These results support our conclusion that exposing pre-service teachers to theoretical knowledge aiming at developing their declarative knowledge about analogies may not be enough for supporting the drawing of good analogies in future.

Many studies have identified that science teachers may have significant difficulties in using analogies (for example: Duit, 1991; Mozzer & Justi, 2013; Treagust et al., 1992; Wilbers & Duit, 2006). Despite this, there are few studies that investigate the origins, or reasons, of such difficulties. As Nottis and McFarland (2001), we recognise the pivotal role of teachers' (pre-service and in-service) education processes in the development of their knowledge on analogies. Therefore, we emphasise the importance of the results of our study since they may support the planning and design of new activities in which teachers could be involved in order to improve their understanding about analogies, and the following more relevant use of them in science teaching.

In this sense, we view as essential that, during their initial training courses, teachers experience a process of drawing and criticising their own analogies. In doing so, they could be able to develop more practical knowledge about analogies and their use in teaching in a way consistent with the practice of science. This could contribute not only to the drawing of analogies that were more consistent with scientific knowledge, but also for improving their recognition of the importance of promoting the use of creative analogies in science teaching. We believe that these strategies could enrich the teachers' training with more authentic views about analogies and make it more likely that teachers use them with all their potential in teaching.

NOTES

[1] Declarative knowledge is that which is made up of propositions concerning concepts, theories, facts, objects, processes etc. that can be expressed verbally or through writing 1995 (Anderson, 1995) for example, define analogies.

[2] Procedural knowledge is that which is made up the cognitive abilities needed to carry out a determined action (Anderson, 1995); for example, know how to draw a good analogy, or in other words, one in which the analogue and the target establish relations of structural and/or functional similarity.

[3] The "come and go" toy (see figure 1) works in the following way: there is a player on either side of the "come and go" toy, each one holding a handle. In opening their hands the child "pushes" the "come and go" to the other player who makes the same movement to return it. In this game, there are no winners or losers.

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REFERENCES

Anderson, J. R. (1995). *Cognitive Psychology and Its Implications*. New York: W. H. Freman.

Aubusson, P. J., Harrison, A. G., & Ritchie, S. M. (2006). *Metaphor and Analogy in Science Education*. Dordrecht: Springer.

Blanchette, I., & Dunbar, K. (2000). How analogies are generated: the roles of structural and superficial similarity. *Memory & Cognition, 28*(1), 108-124.

Clement, J. (2008). *Creative Model Construction in Scientists and Students: The role of imagery, analogy and mental simulations*. Dordrecht: Springer.

Coll, R. K. (2005). The role of models/and analogies in science education: Implications from research. *International Journal of Science Education, 27*(2), 183-198.

Dagher, Z. R. (1995). Analysis of analogies used by science teachers. *Journal of Research in Science Teaching, 32*(3), 259-270.

Davies, J., Nersessian, N. J., & Goel, A. K. (2005). Visual models in analogical problem solving. *Foundations of Science, 10*, 133-152.

Duit, R. (1991). On the role of analogies and metaphors in learning science. *Science Education, 75*(6), 649-672.

Dunbar, K. (2000). How Scientists Think in the Real World: Implications for Science Education. *Journal of Applied Developmental Psychology, 21*(1), 49-58.

Dunbar, K., & Blanchette, I. (2001). The in vivo / in vitro approach to cognition: the case of analogy. *Trends in Cognitive Sciences, 5*(8), 334-339.

Gentner, D. (1989). The mechanisms of analogical learning. In S. Vosniadou & A. Ortony (Eds.), *Similarity and Analogical Reasoning* (pp. 199-241). Cambridge: Cambridge University Press.

Gess-Newsome, J. (2003). *Implications of the Definitions of Knowledge and Beliefs on Research and Practice in Science Teacher Education*. Paper presented at the Annual Meeting of the National Association for Research in Science Teaching, Philadelphia, PA.

Glynn, S. M., Britton, B. K., Semrud-Clikeman, M., & Muth, K. D. (1989). Analogical reasoning and problem solving in science textbooks. In J. Glover, R. Ronning, & C. Reynolds (Eds.), *Handbook of Creativity: Assessment, research and theory* (pp. 383-398). New York: Plenum Press.

Harrison, A. G., & Coll, R. K. (2008). *Using analogies in middle and secondary science classrooms: The FAR guide-an interesting way to teach with analogies*. California: Corwin.

Lederman, N. G., & Gess-Newsome, J. (1999). Reconceptualizing secondary science teacher education. In N. G. Lederman & J. Gess-Newsome (Eds.), *Examining Pedagogical Content Knowledge - The Construct and its Implications for Science Education* (pp. 199-213). Dordrecht: Kluwer.

Mozzer, N. B., & Justi, R. (2012). Students' pre- and post-teaching analogical reasoning when they draw their analogies. *International Journal of Science Education, 34*(3), 429-458.

Mozzer, N. B., & Justi, R. (2013). Science teachers' analogical reasoning. *Research in Science Education, 43*(4), 1689-1713.

Nersessian, N. J. (1992). How do Scientists Think? Capturing the Dynamics of Conceptual Change in Science. In R. N. Giere (Ed.), *Cognitive Models of Science* (pp. 3-44). Minneapolis: University of Minnesota Press.

Nersessian, N. J. (1999). Model-based reasoning in conceptual change. In L. Magnani, N. J. Nersessian, & P. Thagard (Eds.), *Model-based Reasoning in Scientific Discovery* (pp. 5-22). New York: Academic Plenum Publishers.

Nottis, K., & McFarland, J. (2001). A Comparative analysis of pre-service teacher analogies generated for process and structure concepts. *The Electronic Journal of Science Education, 5*(4).

Oppenheimer, R. (1955). *Analogy in science.* Paper presented at the Sixty-Third Annual Meeting of American Psychological Association, San Francisco, California.

Pittman, K. M. (1999). Student-generated analogies: another way of knowing. *Journal of Research in Science Teaching, 36*(1), 1-22.

Treagust, D. F., Duit, R., & Joslin, P. (1992). Science teachers' use of analogies: observations from classroom practice. *International Journal of Science Education, 14*(4), 413-422.

Vosniadou, S. (1989). Analogical reasoning as a mechanism in knowledge acquisition: a developmental perspective. In S. Vosniadou & A. Ortony (Eds.), *Similarity and Analogical Reasoning* (pp. 413-437). Cambridge: Cambridge University Press.

Wilbers, J., & Duit, R. (2006). Post-festum and heuristic analogies. In P. J. Aubusson, A. G. Harrison, & S. M. Ritchie (Eds.), *Metaphor and Analogy in Science Education* (pp. 37-49). Dordrecht: Springer.

Wong, E. D. (1993). Understanding the generative capacity of analogies as a tool for explanation. *Journal of Research in Science Teaching, 30*(10), 1259-1272.

WHAT DO PRE-SERVICE TEACHERS REMEMBER ABOUT THE CONCEPT OF DENSITY?

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Abstract: We present an experience carried out with future primary education teachers. The overall objective was to analyse the difficulties they may have in understanding basic concepts of science, such as the concept of density. Although this concept is treated on many occasions in formal education at the same time that the concepts of mass and volume, our experience shows that even students at university level have not really learned these concepts, and they do not remember beyond the mathematical expression that relates them. This may be due sometimes to the great lack of interest, negative emotions and demotivation they have towards science subjects, such as "Didactics of Matter and Energy", that we teach in the second year of the Degree in Primary Education, and where this work is framed. In this course the students are instructed in scientific and educational content, so they can learn how to teach science in the primary school. The students prepare educational interventions that allow them to significantly transfer the concepts involved to their future 6-12 years pupils. In this work it was first performed a comparative study with a sample of 193 students from the University of Extremadura, to quantify the difference in learning the concept of density between an experimental group and a control group. The experimental group (n = 84) followed a teaching methodology based on the completion of simple laboratory experiments. The control group (n = 109) followed a traditional teaching methodology. Subsequently, both groups performed the same questionnaire to find out what they remembered about the concept of density. The results show statistically significant differences ($p < 0.05$) between both methodologies and reveal the existence of difficulties in the conceptual and experimental understanding of the concept of density.

Keywords: Density, Teacher Training, Misconceptions

INTRODUCTION

There are few studies addressing common scientific understandings held by elementary pre-service teachers (Harrell & Subramaniam, 2014; Dawkins, Dickerson, McKinney, & Butler, 2008; Greenwood, 1996; Stepans, Dyche, & Beiswenger, 1988). As science educators of teachers in training, we would like to know what our students remember about the basic concepts they should explain to their future students of primary education.

Previous studies (Raviolo, Moscato, & Schnersch, 2005) note that, despite being concepts taught in different educational stages, the difficulties in learning them persist in students of all levels, including university. Some authors have analysed this notion and the previous ideas that primary students usually have (Driver, Squires, Rushworth, &Wood-Robinson, 1994). Other studies analyse the different meanings that the term density usually has on the everyday language (heavy, weight, viscous, thick, opaque, numerous…), ideas students may have on higher levels (Llorens, De Jaime, & Llopis, 1989).

Cepni and Sahin (2012) investigate the effectiveness of developed instructional material using various teaching methods and techniques for students' learning of the buoyancy force concept. The sample group consisting of forty-eight students (Control Group=23; Experiment Group=25). The findings suggest students to remedy some misconceptions about the buoyancy force, but do not completely eliminate them. This indicates that it is not easy to alter some students' misconceptions, completely.

Xu and Clarke (2012) reports a detailed analysis of two lessons on density in a 7th Grade Australian science classroom employing the theory of Distributed Cognition. The results of this study suggest that deliberate effort is needed to establish shared understanding not only about the purpose of the activities, but also about the meaning of scientific language and the utility of tools. It also suggests the importance of appropriate employment of instructional resources in order to facilitate student scientific understanding.

Our aim is to identify and analyse previous ideas they may have about that scientific content. If we focus on the primary education curriculum, we have a content module about "Matter and Energy" where we can find a set of initial scientific concepts such as matter, mass, volume and density (specifically, in this experience we will focus on the latter).

METHOD

Objective

The aim of this study was to analyse the persistence of the previous ideas presented by teachers in training on the concept of density after formal instruction, and compare the differences between two groups of students who have used different teaching methodologies. Specifically, one group called “Control Group (CG)" has used a traditional teaching methodology, while the other group, called "Experimental Group (EG)" has followed a methodology based on the completion of simple laboratory experiments.

Sample

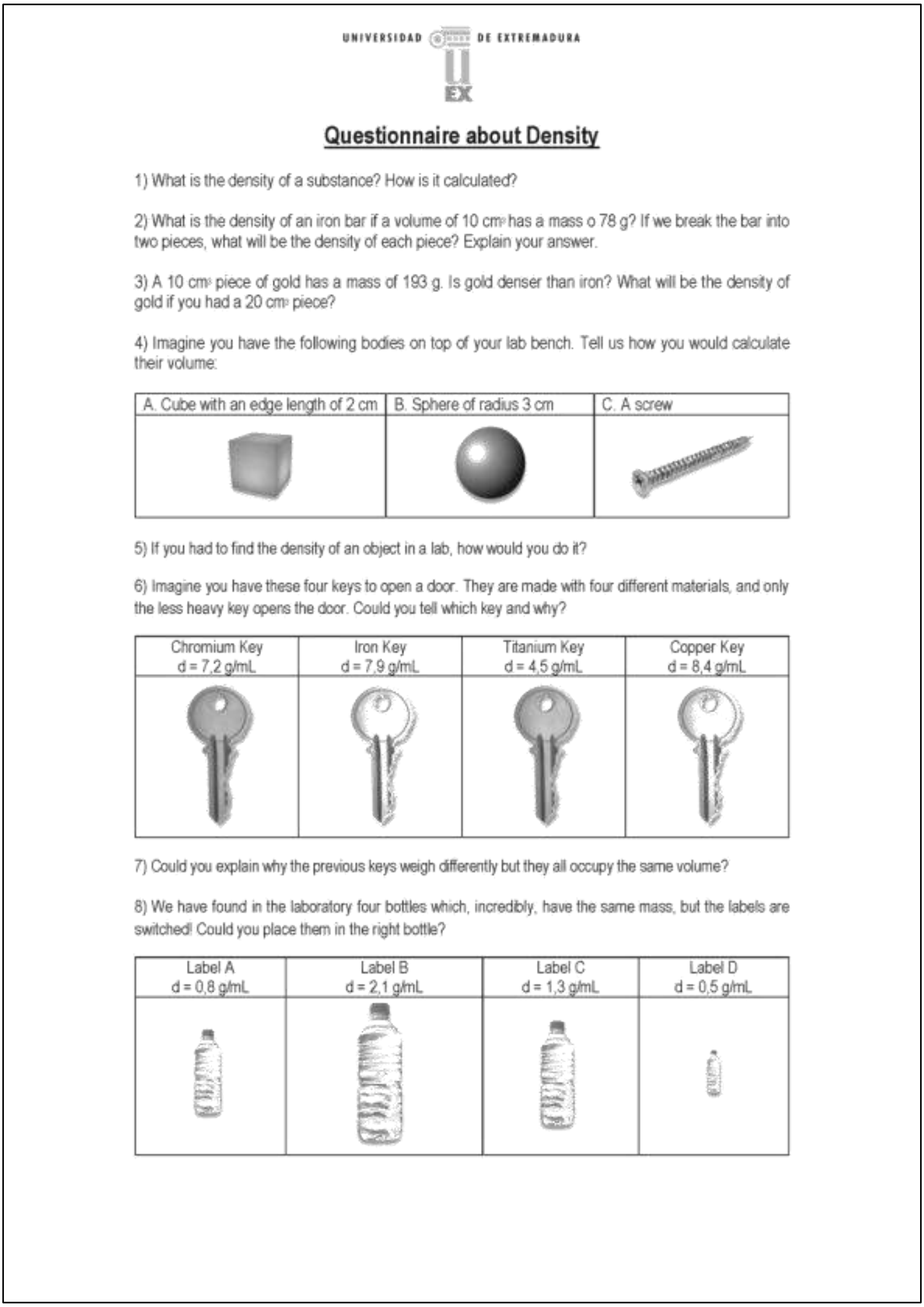
The sample was formed by 193 students (aged 18-21) of the second year of the Degree in Elementary Education from the University of Extremadura, who attended the course of "Didactics of Matter and Energy". This sample was divided into two groups: 109 subjects were part of the Control Group and the remaining 84 subjects were part of the Experimental Group.

Students from CG were divided into 4 groups of 27-28 subjects. They attended a traditional class where the concept of density was explained.

Students from EG were divided into 4 groups of 21 subjects. Each group implemented a laboratory session of 3 hours. Into each group, students worked in pairs. Measures of density of several materials (regular and irregular solids; different liquids) were performed. For example, one of the experiences carried out was aimed at identifying the density of an unknown substance through direct and indirect measurements.

Evaluation tool

A written questionnaire containing 8 questions was used for the detection of previous ideas. This questionnaire is shown in Figure 1.



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Questionnaire about Density

1) What is the density of a substance? How is it calculated?

2) What is the density of an iron bar if a volume of 10 cm^3 has a mass o 78 g? If we break the bar into two pieces, what will be the density of each piece? Explain your answer.

3) A 10 cm^3 piece of gold has a mass of 193 g. Is gold denser than iron? What will be the density of gold if you had a 20 cm^3 piece?

4) Imagine you have the following bodies on top of your lab bench. Tell us how you would calculate their volume:

A. Cube with an edge length of 2 cm	B. Sphere of radius 3 cm	C. A screw

5) If you had to find the density of an object in a lab, how would you do it?

6) Imagine you have these four keys to open a door. They are made with four different materials, and only the less heavy key opens the door. Could you tell which key and why?

Chromium Key d = 7,2 g/mL	Iron Key d = 7,9 g/mL	Titanium Key d = 4,5 g/mL	Copper Key d = 8,4 g/mL

7) Could you explain why the previous keys weigh differently but they all occupy the same volume?

8) We have found in the laboratory four bottles which, incredibly, have the same mass, but the labels are switched! Could you place them in the right bottle?

Label A d = 0,8 g/mL	Label B d = 2,1 g/mL	Label C d = 1,3 g/mL	Label D d = 0,5 g/mL

Figure 1. Questionnaire used in the study

The first question deals about the density. The aim of this question is to get information about the knowledge that students have about this concept, if they are able to provide a scenically correct answer or they just provide the mathematical equation to calculate the numerical value.

The second and third questions have been formulated with the intention of determining whether students have internalized that density is an intensive property of matter, regardless the amount of matter.

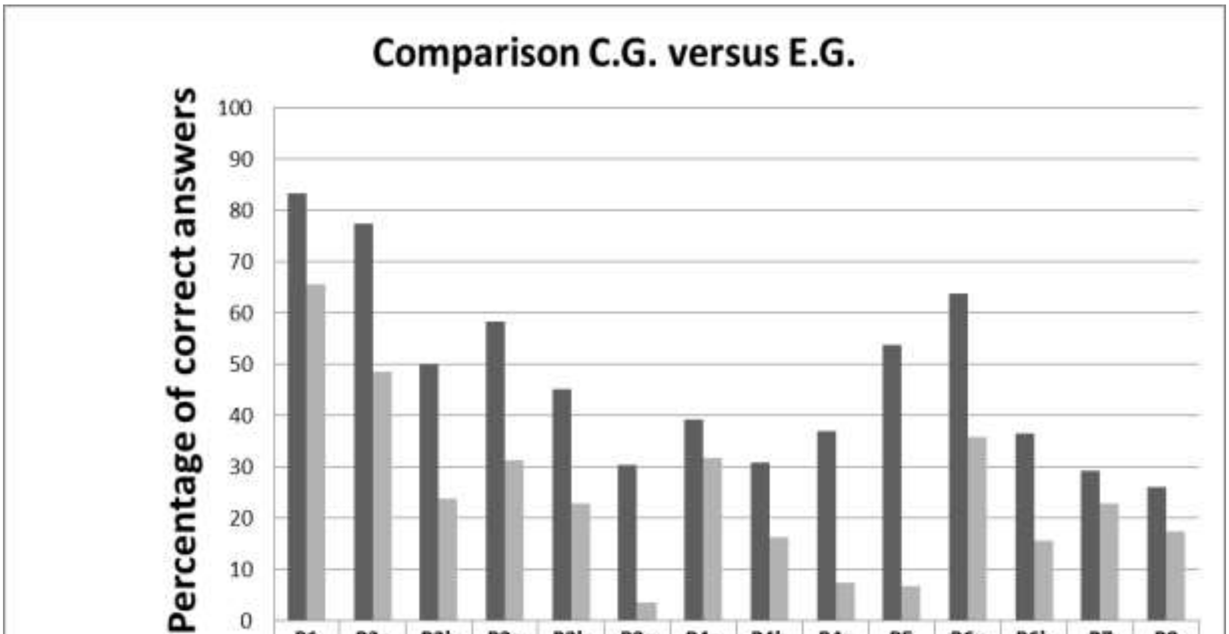
In the fourth question, students are asked to explain how density is calculated in three different solids objects: a cube, a sphere and a screw. This questions aims to establish the knowledge students have about the procedure to measure the volume of geometrical regular and irregular solids.

In the following question, a complement of the previous question, students are asked to explain how to measure the density of an object experimentally.

The following three questions are intended to determine whether students have assumed that the density is not calculated by direct measurement of a variable, from the ratio of two: mass and volume of the object.

RESULTS

Figure 2 shows the results obtained by both groups in the questionnaire. It can be seen that the number of correct answers from the Experimental Group is higher than from the Control Group on all questions, although some results are low on both groups.



	P1	P2a	P2b	P3a	P3b	P3c	P4a	P4b	P4c	P5	P6a	P6b	P7	P8
Experimental Group	83,33	77,38	50,00	58,33	45,24	30,36	39,29	30,95	36,90	53,87	63,69	36,61	29,17	26,19
Control Group	65,60	48,62	23,85	31,19	22,94	3,67	31,65	16,28	7,34	6,88	35,78	15,60	22,94	17,43

Figure 2. Results obtained by both groups in the questionnaire.

From the results shown in Figure 2, we can see differences between the scores of both groups. A Student’s t-test has been carried out on each question, to assess whether the difference in the average of correct answers between the two groups is statistically significant. The results are presented in Table 1. It can be seen that there are significant differences ($p < 0.05$) in questions 1, 2a, 2b, 3a, 3b, 3c, 4b, 4c, 5, 6a and 6b. However, the differences in questions 4a, 7 and 8 are not significant ($p > 0.05$).

Table 1. Statistical results of the comparison of both groups

	T test for equality of means						
	t	Degrees of freedom	Bilateral sig.	Mean Difference (C.G. – E.G.)	Standard error of the difference	95% confidence interval for the difference	
						lower	upper
P1	-2,83	191	0,005	-17,74	6,26	-30,09	-5,39
P2a	-4,25	191	0,000	-28,76	6,76	-42,10	-15,42
P2b	-3,89	191	0,000	-26,15	6,71	-39,38	-12,91
P3a	-3,90	191	0,000	-27,14	6,95	-40,86	-13,43
P3b	-3,35	191	0,001	-22,30	6,65	-35,42	-9,19
P3c	-5,49	191	0,000	-26,69	4,86	-36,27	-17,11
P4a	-1,11	191	0,266	-7,63	6,84	-21,12	5,85
P4b	-2,69	191	0,008	-14,67	5,45	-25,41	-3,93
P4c	-5,74	191	0,000	-29,57	5,14	-39,71	-19,42
P5	-9,55	191	0,000	-46,99	4,92	-56,69	-37,29
P6a	-3,99	191	0,000	-27,91	6,99	-41,69	-14,13
P6b	-3,46	191	0,001	-21,01	6,07	-32,99	-9,04
P7	-0,99	191	0,323	-6,23	6,29	-18,64	6,18
P8	-1,47	191	0,142	-8,76	5,94	-20,47	2,95

DISCUSSION AND CONCLUSIONS

A high percentage of students know the definition of density (Question 1: 84% in the EG and 65% in the CG), offering as the most usual response the formula d = m / V. However, we still find erroneous preconceptions that identify density with weight, mass, thickness, etc. Students are generally able to apply the formula (Questions 2a and 3a), yet they still think that density varies with the amount of substance or the size of a body (Questions 2b and 3c): "if we split an iron bar into two pieces the density of each piece will be half the original density"," if we have twice the volume of gold, density would double". These results are consistent with Dawkins et al. (2008), who found that many middle school pre-service teachers did not fully understand the concept of density, as they just were able to recite the algorithm for density, or perform calculations with the density formula, but failed to understand density as a property of material kind.

In the most experimental questions (4 and 5), the EG results are significantly better than the CG results, as they are more used to laboratory work. However, the percentage of correct answers is low in both groups compared with that obtained in more conceptual questions. According to Hawkes (2004), students who can reason with ratios, which regretfully is less than half of all students, will perceive that all the above follow from d=m/V. Most will not perceive this, and will see no connection between m/V and the concept of density as denseness.

Most students are able to identify the least heavy key (Question 6a), but they fail to provide an elaborated explanation, and they even identify weight or mass directly with density (Question 6b). Moreover, they are unable to explain why the keys have different mass but occupy the same volume (Question 7), and most of them simply explain it by saying that the keys "are made of different material."

Lastly, most students are unable to place the labels in their bottles (Question 8). In this question, the percentage of correct answers is low in both groups when faced with more complex questions, which indicate that pre-service teachers did not fully understand the concept of density.

From the results obtained we can conclude that previous ideas about the concept of density persist at university levels. This is especially serious in the case of students who will be future teachers in primary education, where it is essential to master basic concepts of the science curriculum to properly explain these concepts to their future pupils and to identify their preconceptions. One cause of these results may be due to the methodology of teaching received throughout his school years, so it would be necessary to raise new teaching strategies to foster a really meaningful learning.

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REFERENCES

Cepni, S., & Sahin, C. (2012). Effect of Different Teaching Methods and Techniques Embedded in the 5E Instructional Model on Students' Learning about Buoyancy Force. *Eurasian Journal of Physics and Chemistry Education, 4*(2), 97-127.

Dawkins, K. R., Dickerson, D. L., McKinney, S. E., & Butler, S. (2008). Teaching density to middle school students: preservice science teachers' content knowledge and pedagogical practices. *The Clearing House: A Journal of Educational Strategies, Issues and Ideas*, *82*(1), 21-26.

Driver, R., Rushworth, P., Squires, A., & Wood-Robinson, V. (2013). *Making sense of secondary science: Research into children's ideas*. London, England: Routledge.

Greenwood, A. (1996). When it comes to teaching about floating and sinking, preservice elementary teachers do not have to feel as though they are drowning! *Journal of Elementary Science Education*, *8*(1), 1-16.

Harrell, P. E., & Subramaniam, K. (2014). Teachers Need to Be Smarter Than A 5th Grader: What Pre-service Teachers Know About Density. *Electronic Journal of Science Education*, *18*(6), 1-23.

Hawkes, S.J. (2004). The Concept of Density. *Journal of Chemical Education, 81*(1), 14-15.

Llorens, J. A., De Jaime, M. C., & Llopis, R. (1989). La función del lenguaje en un enfoque constructivista del aprendizaje de las ciencias. *Enseñanza de las Ciencias, 7*, 111-119.

Raviolo, A., Moscato, M., & Schnersch, A. (2011). Enseñanza del concepto de densidad a través de un modelo analógico. *Revista de Enseñanza de la Física*, *18*(2), 93-103.

Stepans, J., Dyche, S., & Beiswenger, R. (1988). The effect of two instructional models in bringing about a conceptual change in the understanding of science concepts by prospective elementary teachers. *Science Education*, *72*(2), 185-195.

Xu, L., & Clarke, D. (2012). Student Difficulties in Learning Density: A Distributed Cognition Perspective. *Research in Science Education*, *42*, 769-789.

SCIENCE TEACHERS' INSTRUCTIONAL EXPLANATION CONSTRUCTION AT DIFFERENT STAGES OF TEACHER EDUCATION

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Abstract: Instructional explanations are essential to science teachers classroom discussion, thus it is important that they are conducive to learning. Currently research into teacher explanations during teacher education is incipient, despite the availability of clear descriptions of effective strategies, components and difficulties experienced by beginner teachers. This study investigated elements used by 97 science and mathematics teachers to explain scientific concepts in simulated classrooms at different stages of teacher education. The participants were six groups of teachers, five of them in initial teacher education of physics-mathematics, biology, chemistry, primary science and one group enrolled in a Master's in Science Education programme. Teachers' explanations were part of micro-teaching episodes videoed and analysed through a rubric previously designed and validated. Results showed similar explaining patterns between groups remaining within teacher education, yet different to the experienced teachers' trend. Student teachers disfavoured metaphors, analogies, models/simulations for explaining concepts, nor addressed pupils' mistakes/misconceptions as a learning opportunities. However, they constructed sequenced explanations containing examples. In-service teachers favoured demonstrations and the connection of the explanation with pupils' experience. The results suggested teacher education requires opportunities to improve teachers' explanation construction and rehearsal from practical perspectives, aided by experience. This study identified the stronger and weaker explanation elements of teachers' precluding real and practical experience. The discussion encompassed opportunities for developing this crucial practice, and suggestions for decision-makers regarding the teacher transition into the labour context.

Keywords: instructional explanations, teacher education

INTRODUCTION

Discussions about teacher education highlighted the need for quality teaching practices and knowledge (Lawson, Askell-Williams, & Murray-Harvey, 2009). Helping student teachers construct effective teaching practices requires progressive and analytic work to identify good practice and rehearsal ((Borman, Mueninghoff, Cotner, & Frederick, 2009; Inoue, 2009; Sonmez & Can, 2010). Knowledge conducive teaching practices are considered high-leverage practices (Ball, Sleep, Boerst, & Bass, 2009), and one of these is making content explicit through explanations and models. Instructional explanations are actions to communicate some part of the subject matter to the learners and support their understanding (Leinhardt, 2001), usually embedded in teacher-talk (Wittwer & Renkl, 2008), forming an important part of science teachers' work (Geelan, 2013; Preiss, Alegría, Espinoza, Núñez, & Ponce, 2012).

Although qualities of explanation desired for learning promotion are clear (see Ogborn, Kress, Martins & MGillicuddy, 1996; Thagard, 1992; Treagust & Harrison, 1999), there is evidence that teachers at their last stage of preparation struggle to construct understandable explanations for pupils (Cabello & Topping, 2014; Charalambous, Hill, & Ball, 2011; Inoue, 2009). This is a problem considering that practically, teacher explanations often fail in the purpose of conducting pupils' understanding (Wittwer & Renkl, 2008), especially in the scientific area of teaching (Zangori & Forbes, 2013). This problem is particularly relevant statistically to Chile, where around 80 % of in-service teachers construct explanations deficiently according to the national assessment of teacher performance (Gobierno de Chile, 2013; Manzi, González, & Sun, 2011). In this national measurement, good quality explanations are considered as containing examples and delivered in a clear language for the audience (Manzi et al., 2011). Furthermore, research into teacher explanation construction, particularly during teacher education is incipient (Geelan, 2012; Hillier, 2013).

Prior research has shown that pre-service teacher explanations are widely dependent on the content being taught (Inoue, 2009), and that practices to explain differ according to pre-service teachers knowledge and beliefs about the topics (Charalambous et al., 2011). The few studies oriented to improve pre-service teachers' explanations during initial teacher education have found that explaining is a skill that can be learned using techniques such as rehearsal, microteaching, coaching or peer assessment (Cabello & Topping, 2014; Charalambous et al., 2011; Hillier, 2013; Inoue, 2009). These alternatives are likely to conduct pre-service teachers to the development of pedagogical content knowledge (Cabello & Topping, 2014; Hillier, 2013), which is the special type of knowledge to transform erudite content into an understandable amalgam for the students to learn (Shulman, 1986). However, the extent to which pre-service teacher explanations might differ between the subject matter of the teacher preparation programme and the progression of the skill of explaining at different stages of teacher education programme have not been explored by empirical research.

The current study was exploratory and descriptive. It sought to investigate the characteristics and elements used by science and mathematics pre-service teachers to construct explanations for the classroom. It analysed teacher explanation construction in six groups of teachers in Chile –five of them in under-graduate levels and one in a Master's in Science Education programme- using videoed simulated micro-teaching. The research questions were: What are the characteristics of science and mathematics teacher explanations at different stages of teacher education programmes? Are they dependent on subject matter? We hypothesized that teachers at the last stage of undergraduate preparation programme and teachers in the Masters' level would display enhanced characteristics associated with pupils' learning promotion. Also, different patterns of explanation may occur according to subject matter. A rubric previously validated for formative assessment based on literature review was used to identify regularities and differences in teachers' explanations (Cabello, 2014).

METHOD

The study had an exploratory and quantitative design. Three universities with teacher preparation programmes were chosen because of their similarity and representative nature. They were located in an urban zone of Santiago, the capital of Chile.

The participants were six groups of teachers, five of them in different stages of initial teacher education of physics-mathematics, biology, chemistry, primary science and one group enrolled in a Master's in Science Education programme. In total, 97 teachers voluntarily agreed to perform a micro-teaching episode which was videoed. They signed an informed consent and the authorities of the universities also gave written permits following ethical guidelines from Universidad de Chile. The composition of the groups is presented in Table 1 and 2.

Table 1. Participants by subject matter.

Subject Matter Area	Participants
Physics	24
Mathematics	27
Biology	10
Chemistry	17
Primary science	17
Master's in Science Ed.	5

Table 2. Participants by year of study.

Year of study	Participants
3rd	21
4th	36
5th	35
Postgraduate	5

The video-recorded microteaching episodes were analysed by the researcher and a trained research assistant in order to detect regularities and differences in participants' explanations. The coding process was conducted using a rubric previously validated (Cabello, 2014), which contained elements taken from literature review each one with three levels of achievement; 0 not achieved, 1 partially achieved and 2 achieved.

In this study, the three new elements –SQ11, SQ12 and SQ13- were added as summarised in Table 3. For reliability, 30 per cent of the videos were double-blinded marked and 89.2 per cent of inter-judge agreement was reached. Cohen's Kappa was calculated and it was 0.64.

Table 3. Components of rubric for the analysis of explanations.

ID	Component	Description
SQ1	Clarity	How clear the language and presentation of the concept explained are
SQ2	Coherence and cohesion	How consistent and connected the parts of the explanation are
SQ3	Sequence (organization)	How progressive the parts of the explanation are presented
SQ4	Conceptual accuracy	How precise the use of scientific terms and algorithms are in the explanation
SQ5	Completeness	To what extent the explanation is sufficient for the aimed conceptual understanding
SQ6	Connection with students' experience	How connected the explanation is with the students' pre-concepts, ideas or prior experiences
SQ7	Metaphor, analogy, simulation or model	How these teaching devices are used in the explanation to help students to interpret/represent the concept
SQ8	Example, graph or image	How these teaching devices are used in the explanation to help students to construct the concept
SQ9	Use of non-verbal language	How representational gestures and voice inflections are used in the explanation
SQ10	Treatment of errors as learning opportunities	How the common misconceptions are addressed/treated

SQ11	Relevance reference	How the relevance of learning the concept is introduced in the explanation
SQ12	History, philosophy or nature of science	How elements related to this approach are included in the explanation
SQ13	Demonstration and experiments	How these science teaching devices are used in the explanation

Quantitative analysis was run using SPSS™ package (IBM Corp., 2010). Comparison of frequencies was done for the groups to explore similarities and differences. With the similar-sized groups also comparison of means was applied using ANOVA test for independent samples.

RESULTS

The participants' explanations average length was 9:19 minutes. In general, similar patterns were found between student teacher groups in initial teacher education, higher for teachers in Master's degree. The pattern indicated that student teachers constructed coherent and cohesive explanations with examples or images as concept illustration, but did not address pupils' mistakes or misconceptions as a learning opportunity. Actually, they ignored them when appeared or corrected immediately giving the correct answer, without inquiring the causes of the misconceptions or exploring the ideas that could change. Likewise, they did not broader the relevance of concepts, nor referred to history or philosophy of science and used limited demonstrations/ experiments, metaphors, analogies, models in their explanations. These findings are presented in Figure 1.

The components of explanations that presented more differences were the accuracy of the explanation, the completeness and the connection of the explanation with pupils' experience.

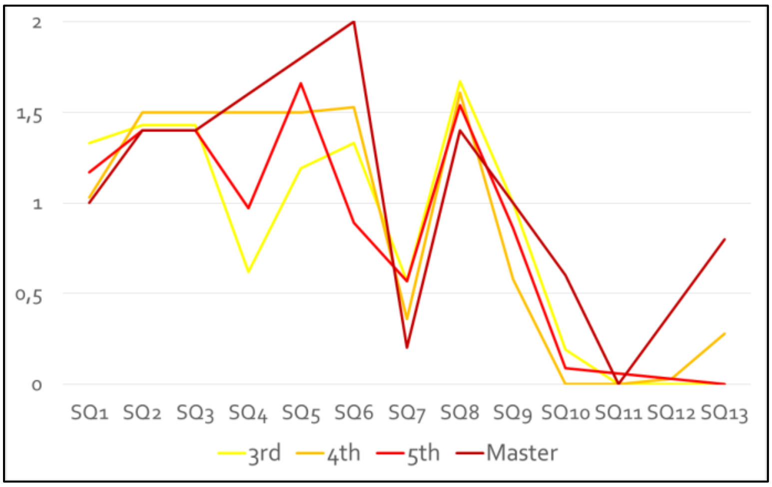

Figure 1. Trends in explanations by teacher education stage.

When exploring the patterns by subject matter, a different scenario appeared. In the general pattern the differences were not statistically significant by subject matter group. However, there were variations in some of the criteria. The biology group was significantly lower than the other groups in the accuracy of the explanation, as well as in its sufficiency or completeness. Also, differences were found in the incorporation of pupil's experiences in the explanation, in which Chemistry pre-service teachers obtained the lowest level followed by Biology teachers as shown in Figure 2.

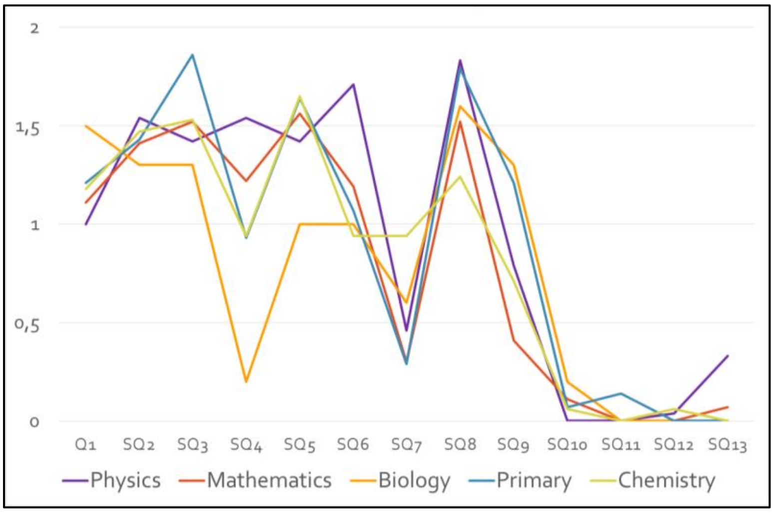

Figure 3. Trends in explanation by subject matter

DISCUSSION AND CONCLUSIONS

All student teachers but participants from the Physics group presented difficulties integrating pupils' experiences into explanation, contrastingly, this skill was enhanced for in-service teachers' explanations. This is interesting because it was not expected by the researcher. The strength of this group of teachers could have been the usage of demonstrations or experiments because of the characteristics of the contents in this subject matter. However, in this group of pre-service teachers this criterion was slightly higher than in the other groups.

Likewise, a result that implies an important interpretation is the lack of accuracy in explanations of Biology pre-service teachers. It seems that this group struggle with the transformation of the contents for teaching, which demonstrates not only weaknesses in the content knowledge but also lack of pedagogical content knowledge (Shulman, 1986). This finding is relevant to report to decision makers in initial teacher education in the context of this study.

Moreover, the patterns obtained in this study suggest that more teaching experience during initial teacher education by itself is not linked with improvements in the pre-service teachers' explanations, because the differences between the stages were not as high as expected. This reinforces the need of rehearsal from the earlier stages (Inoue, 2009) as well as the training of skills to analyze practical components of teaching (Sonmez & Can, 2010). Also, the results indicated that teacher education in the context of the study requires opportunities to improve teacher explanation construction from theoretical and practical perspectives based on effective explanations (Treagust & Harrison, 1999), aided by experience.

Another relevant element to report to initial teacher education is the need of remedial actions to improve the components that were almost absent from this analysis of teaching performance. For instance, metaphors, analogies, models and simulations were rarely presented, which contrast with the well-known benefits of using these types of teaching devices (Ogborn & Martins, 1996; Treagust, 1998). Similarly, treating common misunderstandings or misconceptions as an opportunity for learning is an effective way of teaching constructively that did not seem to be plausible for this group of teachers. Additionally, more support is needed to introduce history, philosophy or nature of science approach in new teachers' explanations. There remains a challenge for teacher education curricula to incorporate the benefits of this approach and exemplified diversification to explanation skills, within early teaching experiences and the transition to real teaching. It transcends the local interest of researchers, teacher educators and decision-makers to address this issue before student teachers start their transition to real teaching contexts.

This study identified through a rubric specific elements and patterns by diverse groups of science and mathematics teachers during teacher education programmes. This identification revealed the need of more diverse types of analysis and rehearsing, helping to focus the strategies to the specific weak areas. The limitations of the study comprise the group size differences, which restricted more sophisticated statistical analysis. Also, as the participants were voluntary, influence of self-selection variables should be considered.

As a projection of this study there is the possibility of comparing the patterns obtained during teacher education programmes versus real classroom environment teaching performance. This is mentioned because simulated classrooms perhaps diminished realism and affected more interactive components of explanations such as the incorporation of pupils' experiences.

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REFERENCES

Ball, D. L., Sleep, L., Boerst, T., & Bass, H. (2009). Combining the development of practice and the practice of development in teacher education. *Elementary School Journal., 109*, 458-476.

Borman, K. M., Mueninghoff, E., Cotner, B. A., & Frederick, P. B. (2009). Teacher preparation programs. In L. J. Saha & A. G. Dworkin (Eds.), *International Handbook of Research on Teachers and Teaching* (Vol. 21, pp. 123-140): Springer US.

Cabello, V. (2014). Assessment of pre-service science teachers' explanations: a rubric to explore how they communicate scientific concepts. *Journal of Science Education, 15*(Special), 98.

Cabello, V., & Topping, K. J. (2014). Learning how to make scientific concepts explicit in teacher education: A study of student teachers' explanations, their modifiability and transference. *Pensamiento Educativo. Revista de Investigación Educacional Latinoamericana 51*(2), 86-97.

Charalambous, C., Hill, H., & Ball, D. (2011). Prospective teachers' learning to provide instructional explanations: how does it look and what might it take? *Journal of Mathematics teacher education, 14*(6), 441-463. doi: 10.1007/s10857-011-9182-z

Geelan, D. (2012). Teacher explanations. In B. J. Fraser (Ed.), *Second international handbook of science education* (pp. 987-999). Dordrecht, The Netherlands: Springer.

Geelan, D. (2013). Teacher explanation of physics concepts: a video study. *Research in Science Education, 43*(5), 1751-1762.

Gobierno de Chile. (2013). *Resultados nacionales de la evaluación docente 2012*. Santiago de Chile: Ministerio de Educación.

Hillier, J. (2013). How does that work? Developing pedagogical content knowledge from subject knowledge. *Teacher Education and Practice, 26*(2), 321-338.

IBM Corp. (2010). IBM SPSS statistics for Windows (Version 19.0.). Armonk, NY: IBM Corp.

Inoue, N. (2009). Rehearsing to teach: content-specific deconstruction of instructional explanations in pre-service teacher training. *Journal of Education for Teaching, 35*(1), 47-60. doi: 10.1080/02607470802587137

Lawson, M. J., Askell-Williams, H., & Murray-Harvey, R. (2009). Dimensions of quality in teacher knowledge. In L. J. Saha & A. G. Dworkin (Eds.), *International Handbook of Research on Teachers and Teaching* (Vol. 21, pp. 243-257): Springer US.

Leinhardt, G. (2001). Instructional explanations: A commonplace for teaching and location for contrast. In V. Richardson (Ed.), *Handbook of research on teaching* (4 ed., pp. 333-357). Washington, DC: American Educational Research Association.

Manzi, J., González, R., & Sun, Y. (2011). *La evaluación docente en Chile*. Santiago de Chile: MIDE UC.

Ogborn, J., & Martins, I. (1996). Metaphorical understandings and scientific ideas. *International Journal of Science Education, 18*(6), 631 - 652.

Preiss, D., Alegría, I., Espinoza, A. M., Núñez, M., & Ponce, L. (2012). *¿Cómo se enseña la ciencia en la escuela? Evidencia de un estudio audiovisual en aulas de escuelas públicas chilenas.* Paper presented at the Segundo congreso interdiscipinario de investigación en educación, Santiago, Chile.

Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher, 15*, 1-14.

Sonmez, D., & Can, M. H. (2010). Preservice science teachers' ability to identify good teaching practices. *Procedia - Social and Behavioral Sciences, 2*(2), 4120-4124. doi: http://dx.doi.org/10.1016/j.sbspro.2010.03.650

Treagust, D. (1998). Teaching science effectively with analogies: An approach for preservice and inservice teacher education. *Journal of Science Teacher Education, 9*(2), 85.

Treagust, D., & Harrison, A. (1999). The genesis of effective scientific explanations for the classroom. In J. Loughran (Ed.), *Researching teaching: Methodologies and practices for understanding pedagogy*. London: Routledge.

Wittwer, J., & Renkl, A. (2008). Why instructional explanations often do not work: A framework for understanding the effectiveness of instructional explanations. *Educational Psychologist, 43*(1), 49-64.

Zangori, L., & Forbes, C. T. (2013). Preservice elementary teachers and explanation construction: Knowledge-for-practice and knowledge-in-practice. *Science Education, 97*(2), 310-330. doi: 10.1002/sce.21052

PRE-SERVICE SCIENCE TEACHERS' UNDERSTANDING AND ATTITUDES TO INQUIRY

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Abstract: Inquiry based learning has been widely promoted as a suitable method for learning science over the past two decades. Research has shown that there are many challenges faced by teachers who are attempting to implement inquiry instruction in their classrooms. These challenges or barriers need to be overcome so that inquiry learning may be implemented effectively. Pre-service teacher education programmes based on the ESTABLISH in-service training programmes were developed and implemented in eight institutions across Europe. The aim of this research was to determine if the participating pre-service teachers (N=217) have a greater understanding and attitude to inquiry following inquiry teacher education programmes and if the challenges that they face when implementing inquiry have changed. The teachers' responses relating to their understanding of inquiry and attitudes towards inquiry were analysed using a statistical technique called multidimensional scaling (MDS). Multidimensional scaling (MDS) is a statistical analysis technique that is used to graphically display the similarities or dissimilarities between objects. These teacher education programmes were successful at introducing participants to inquiry instruction and improvements in their attitudes to inquiry we also observed. The challenges to implementing inquiry in the classroom identified by the participants were mainly extrinsic factors. These challenges did not shift over the duration of the teacher education programme.

Keywords: Pre-service Teachers, Inquiry in Science Education, IBSE, Attitudes

INTRODUCTION

Inquiry based learning has been promoted as a suitable method for learning science in various reports and curriculum documents (National Research Council, 2000; Minner, Levy, & Century, 2010). Twenty years ago in the National Science Education Standards document, the National Research Council asserted that inquiry is central to science learning and that when students are engaged in inquiry they "*describe objects and events, ask questions, construct explanations, test those explanations against current scientific knowledge, and communicate their ideas to others. They identify their assumptions, use critical and logical thinking, and consider alternative explanations*." They state that from this, students' understanding of science is developed due to the combination of scientific knowledge with thinking and reasoning skills (National Science Education Standards, 1996, p. 13)

Linn, Davis and Bell note that teachers must create environments where students can implement inquiry, where there is an "*intentional process of diagnosing problems, critiquing experiments, and distinguishing alternatives, planning investigations, researching conjectures, searching for information, constructing models, debating with peers, and forming coherent arguments*" (Linn, Davis, & Bell, 2004).

Therefore, teachers must be knowledgeable and proficient in inquiry and inquiry practices so that they can create suitable environments. However, research has shown that there are many challenges faced by teachers who are attempting to implement inquiry instruction in their classrooms. These challenges or barriers need to be overcome so that inquiry learning may be facilitated effectively. Implementing inquiry successfully in the classroom is not simply about possessing the correct curriculum materials. The teacher must possess an appropriate attitude towards inquiry, where they believe both in the value of the inquiry process and of allowing students to have at least some control over what they are doing (Colburn, 2000). One of the main challenges faced by teachers in inquiry instruction is their lack of understanding of inquiry and how to implement it effectively in the classroom. Without an understanding of how inquiry works and what the role of the students and teachers are in the classroom, then it is unlikely that inquiry will be conducted effectively (Crawford, 2000; Roehrig & Luft, 2004; Hong & Vargas, 2016; ESTABLISH, 2014).

Teachers often believe that inquiry takes up too much time and as a result may struggle to cover the curriculum due to their already packed teaching load. Good inquiry lessons require planning prior to the class, and often involve a lot of practical work which may seem like too time consuming for the teachers (Hammer, 1997; Anderson, 2007; Lehman, George, Buchanan, & Rush, 2006; Jackson & Boboc, 2008). Jackson and Boboc also highlighted concerns about managing the inquiry class such as safety issues, materials needed and facilities required the inquiry, unequal distribution of work during group work, getting students' attention, and providing makeup work for those students who have missed an inquiry-based activity (Jackson & Boboc, 2008).

Pre-service teachers need to be aware of the challenges and also have strategies to deal with these issues. A professional development programme aimed at preparing pre-service teachers to facilitate inquiry learning in the classroom should therefore support teachers addressing these challenges.

Teacher Education Programmes

Analysis of more than 200 studies by Joyce and Showers identified features of effective professional development, which alone, and together, contribute to the effect of the training programme. The major components that were identified in the reviewed studies include:

1. "*Presentation of theory or description of skill or strategy,*
2. *Modelling or demonstration of skills or models of teaching,*
3. *Practice in simulated and classroom settings,*
4. *Structured and open-ended feedback (provision of information about performance),*
5. *Coaching for application (hands-on, in-classroom assistance with the transfer of skills and strategies to the classroom)"* (Joyce & Showers, 1980, p. 380)

Another reported element that is integral in the organisation and running of an effective professional development programme is the time of the training programme itself. Joyce & Weil have claimed that it takes at least 30 hours of training to perfect a new teaching method and make a substantial permanent change in their practice (Joyce & Weil, 1986).

Specific to inquiry, Anderson has suggested some key factors for introducing teachers to inquiry instruction. Good teaching material should be provided to the participating teachers, there should be opportunities for discussing teaching materials with their colleagues, and guidance should be made available on how to develop their own teaching materials. Finally, he recommends that teachers are afforded support following the programme in their attempts to implement inquiry instruction (Anderson, 2007).

There are particular issues when providing professional development for pre-service teachers. As part of their education pre-service teachers will encounter and discuss various different methodologies and inquiry may not stand out as a methodology that they would like to implement. There may be very little opportunity for the pre-service teachers to trial inquiry with students or simply have insufficient time to trial it.

The aim of this research was to determine if pre-service teachers have a greater understanding and attitude to inquiry following inquiry teacher education programmes and if the challenges that they identify when implementing inquiry have changed.

METHODOLOGY

Pre-service teacher education programmes based on the ESTABLISH in-service training programmes were developed and implemented through eight institutions across Europe (ESTABLISH, 2014). In some cases the programmes were stand-alone workshops completed in addition to the pre-service teachers' training, and in other cases the inquiry programme was incorporated and embedded within the participants' existing modules. In each case, experiencing inquiry themselves was a key component, in addition to learning how to implement and develop inquiry in the classroom.

Questionnaires were developed for distribution to pre-service teachers before and after the teacher education programme. Questionnaires were developed to determine pre-service teachers' understanding of inquiry, attitudes to inquiry and challenges faced when implementing inquiry. These questionnaires were completed on a pre-post teacher education programme basis.

Items in the questionnaire related to understanding of inquiry and attitudes towards inquiry are Likert-type questions. The responses were on a five point scale which ranged from strongly disagree to strongly agree. To determine what the participants considered to be a challenge when attempting to implement inquiry, they were provided with a list of selections including an "other" option and they indicated what they believed to be their top three challenges.

This study involved 217 pre-service teachers from seven institutions across Europe (Ireland, the Czech Republic, Italy, Poland, Slovakia, and Germany). Only countries that provided responses to the pre and post questionnaire are included in the analysis. Over 70% of the participants in this study were less than 25 years old, which represents a very narrow spread of age. 71% of the cohort was female and over three quarters of the total group had between 0 and 20 weeks teaching experience.

Participants were also asked to rate their experience with inquiry based science education. They classified themselves as either being a beginner with inquiry, having some experience with inquiry, or being very experienced with inquiry. 69% of the pre-service teachers rated themselves as beginners with inquiry, 30% said that they had some experience with inquiry, and less than 1% said they were very experience with inquiry.

MULTIDIMENSIONAL SCALING

The teachers' responses relating to their understanding of inquiry and attitudes towards inquiry were analysed using a statistical technique called multidimensional scaling. Multidimensional scaling (MDS) is a statistical analysis technique that is used to graphically display the similarities or dissimilarities between objects. MDS is capable of modelling nonlinear relationships between variables, it does not require multivariate normality, and ordinal or nominal data may be used (Jaworska & Chupetlovska-Anastasova, 2009). As such, it can be an alternative to other multivariate techniques such as cluster analysis or factor analysis, but it can also be used in conjunction with other techniques (Arce & Garling, 1989). The principal aim of this kind of analysis is to generate a configuration of points whereby the distance between these points match as close as possible to the proximities between these objects (Kruskal, 1964).

The distribution of the responses based on each teacher cohort is analysed by multidimensional scaling (MDS) and mapped relative to a most positive ("ideal") response. . As the multidimensional scaling maps are generated based on the given inputs, if any one input is changed then the entire map changes and the points would change position. This is important to note when differences are observed between maps showing only pre-TEP data and maps showing both pre and post-TEP data.

To analyse this data an average response to each question was obtained per country. Particular questions were then grouped together (e.g. questions asking them to rate their understanding of IBSE, as well as their understanding of the role of a teacher and the role of the students in the inquiry classroom were considered as one grouping) The responses to each individual question in the group was then combined and used as inputs for the analysis and the statistical technique reduced the responses of several questions for each country to just one data point on a map. This allows for inter-country comparisons to see similarities between different country cohorts as well as similarities of particular cohorts to the most positive (ideal) response.

RESULTS

Pre- Teacher education Programme

Understanding of Inquiry

Teachers' overall understanding of inquiry is determined from their responses to questions asking them to rate their understanding of IBSE, as well as their understanding of the role of a teacher and the role of the students in the inquiry classroom. The most positive or "ideal" response is that of fully understanding IBSE and the roles of teacher and student in an inquiry classroom. Looking at the teachers' understanding of inquiry there are clear differences between the country cohorts. Results from MDS were plotted on MDS map. Each country cohort is shown as a different letter (A, B, C, D, E, J, K). From Figure 1, it is clear that there are two distinct clusters and one outlier, cohort C. Cohort C was uncertain about all three statements. No country cohort provided responses that were similar or close to the ideal response prior to the teacher education programme.

Attitudes towards Inquiry

The most positive response for attitudes towards inquiry would indicate that the teachers think inquiry does not take up too much time to implement, inquiry is suitable for achieving the aims of the curriculum and that inquiry is not suitable for very capable students. From Figure 2 it is clear that there are two distinct clusters which are not located near the ideal response. Looking at the teachers' attitudes towards inquiry differences between the country cohorts are clear. Overall, the participants in cluster 1 (B, D, J and K) disagreed more with the statements "I think inquiry takes up too much classroom time for me to implement" and "Inquiry based teaching is only suitable for very capable students" than cluster 2 (A, C and E). However, the participants in cluster 2 were slightly more in agreement with the statement "The use of inquiry is appropriate to achieving the aims of the curriculum", than cluster 1. It is important to note that no country cohort provided responses that were similar or close to the ideal response prior to the teacher education programme.

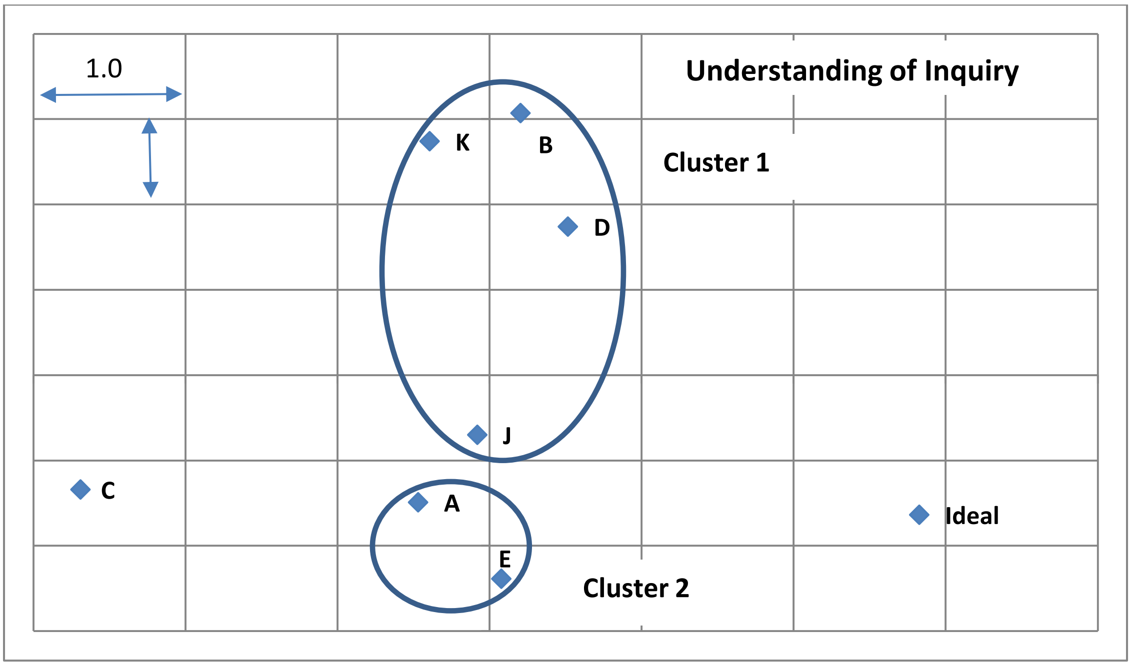

Figure 1: MDS diagram for Understanding of Inquiry based on pre-TEP

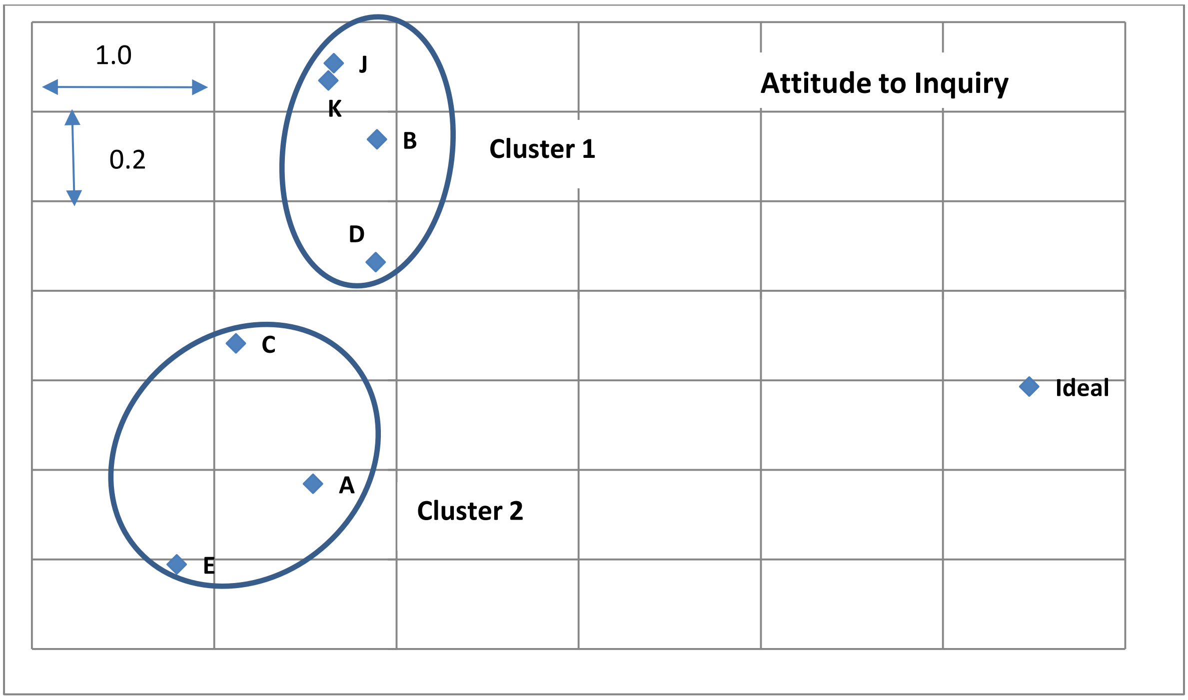

Figure 2: MDS diagram for Understanding of Inquiry based on post TEP

Post- Teacher education Programme

Understanding of Inquiry

Following the teacher education programmes in each country, there were shifts in the responses of many of the cohorts (Figure 3). However, there was a greater change and a more positive change by some cohorts more than others. Cohort (C) was initially furthest from the ideal as they indicated that they were uncertain about whether they understood inquiry, the role of the teacher, and the role of the student in the inquiry classroom. Following the TEP, this cohort have clearly moved towards the ideal, showing greater understanding of inquiry. The arrows indicate some of the greater shifts observed and the * denotes the position of the country cohort following the TEP. Cohort C has shown the greatest movement; however positive changes are also noted for cohorts B, E and K. Changes in cohorts D, J and A are less evident.

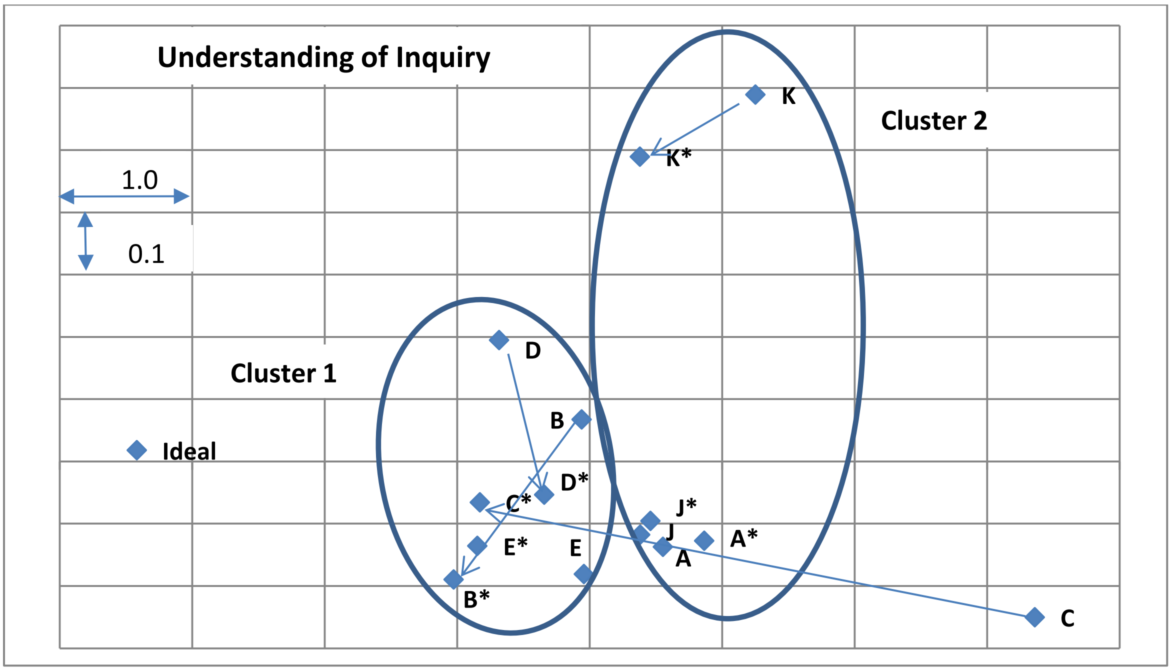

Figure 3: MDS diagram of Understanding of Inquiry, based on matched pairs, per cohort (* denotes responses after teacher education programme)

Analysis is ongoing to determine if there are any relationships between the responses given and the prior experience level of the pre service teachers with inquiry in the classroom. Also the potential impacts of the duration of the teacher education programmes are being analysed.

Attitudes towards Inquiry

The change in responses by each cohort after the teacher education programme in terms of their attitude to inquiry is shown in Figure 4, showing a shift towards the ideal by cohorts A and C. Generally, cluster 2 (A, A*, C, E and E*) are more uncertain towards all three statements than cluster 1 (B, B*, C*, D, D*, J, J*, K and K*), who disagree that "inquiry takes up too much classroom time for me to implement" and that "Inquiry based teaching is only suitable for the very capable students". Further analysis is required to determine if the changes that are observed is related to the prior inquiry experience of the pre-service teachers or their prior experience in teaching in schools.

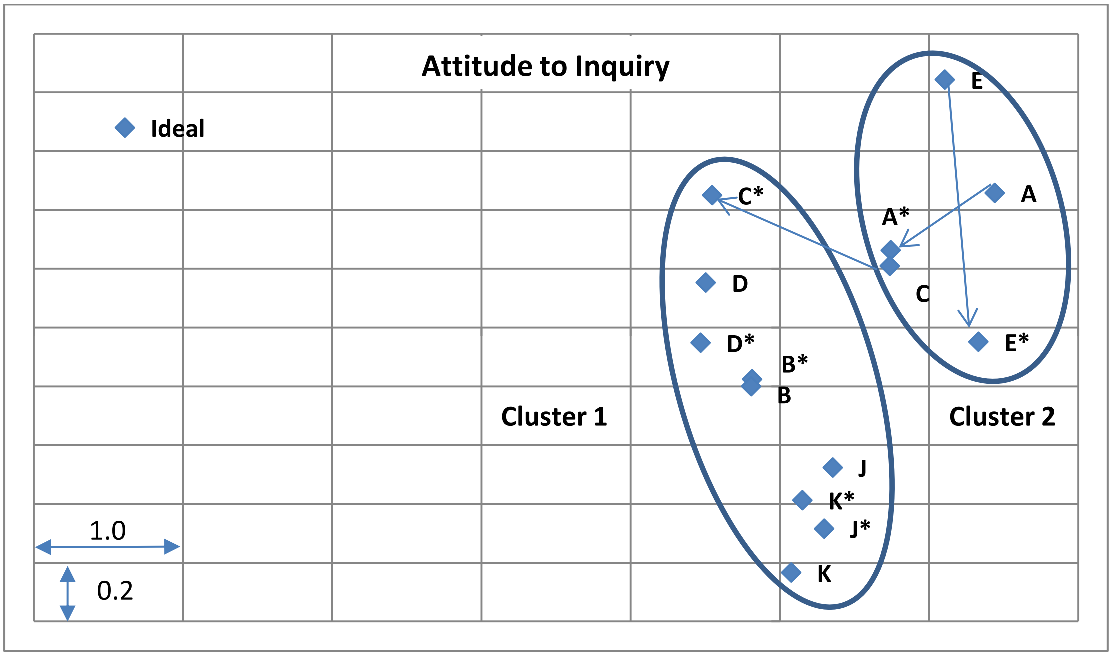

Figure 4: MDS of Attitude to Inquiry, based on matched pairs, per cohort (* denotes responses after teacher education programme)

Challenges Faced

Prior to the teacher education programme, the lack of time to implement inquiry and absence of assistance in school laboratories were the primary challenges faced by the pre-service teachers when trying to implement inquiry lessons, as shown in Figure 5. The main challenges noted are identical to those mentioned earlier for practicing teachers, i.e. time to implement and hence lack of time to cover curriculum.

Following the teacher education programme, the greatest challenges faced by the participants remained the same. Analysis is ongoing to determine if there are any relationships between the challenges identified and the prior experience level of the individual teachers with inquiry in the classroom.

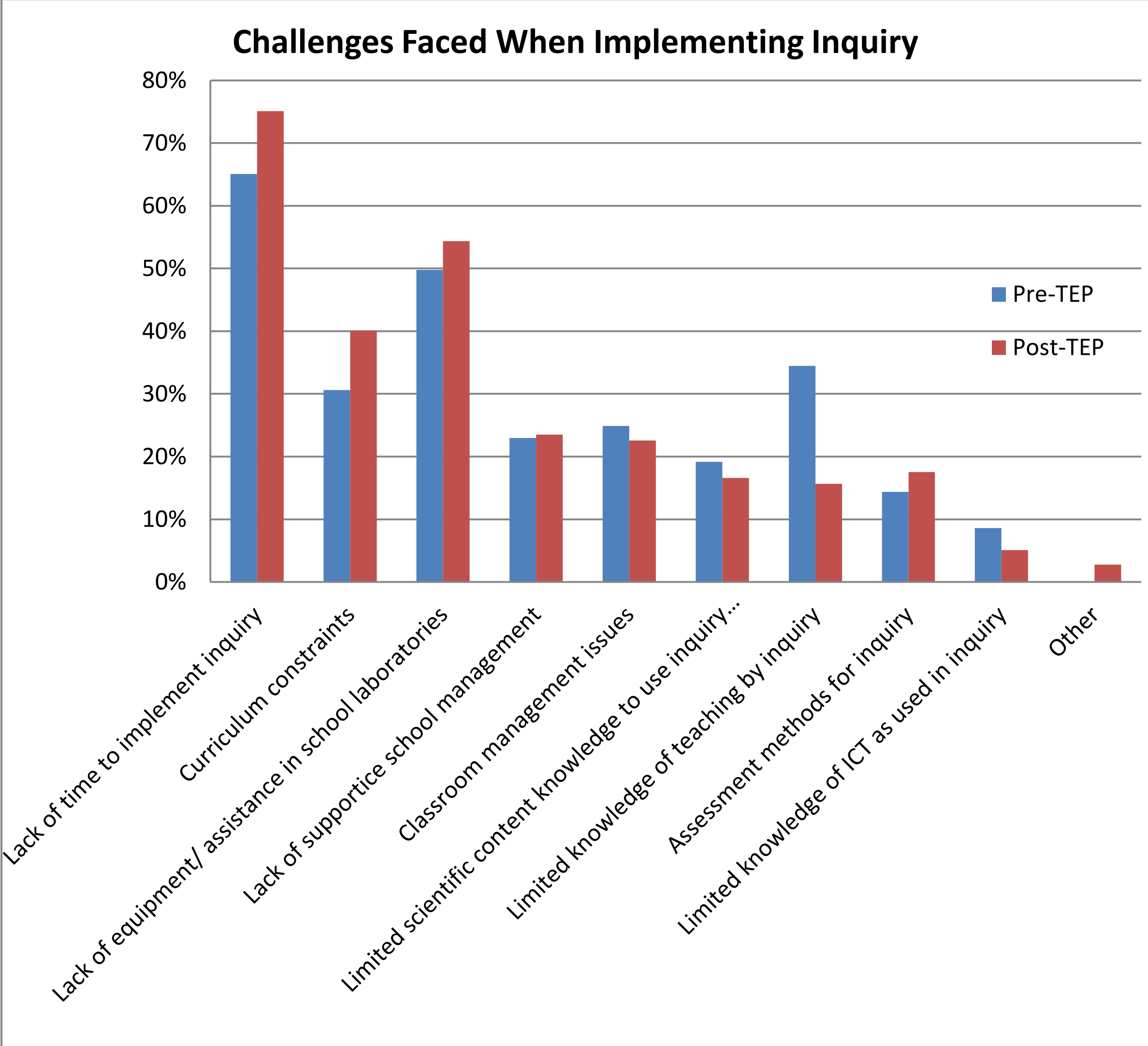

Figure 5: Challenges when implementing inquiry in the classroom

DISCUSSION AND CONCLUSION

The teacher education programmes were successful at introducing participants to inquiry instruction. There were some positive increases in understanding of inquiry and in attitudes towards inquiry. The lack of movement in the MDS analysis by some cohorts demands greater analysis. As these MDS maps have only shown the cohort from each country, the background of each member of the cohort needs to be taken into account. There is a variation in the amount of teaching experience that the participants have and this may have influenced their attitudes to use of inquiry in the classroom. Likewise the structure and overall programme of pre-service training may have an important influence.

Although longer training times are recommended (Joyce & Weil, 1986), these results show that with a short programme (as little as 8 hours contact) you can effect change in pre-service teachers' understanding and attitudes to inquiry. However, longer teacher education programmes would help to embed attitudes and overcome challenges.

Looking at the types of challenges faced by the participants, the challenges are mainly extrinsic in nature, suggesting that participants are primarily impeded by external issues. These challenges did not shift over the course of the teacher education programme. Some intrinsic challenges were considered less of a barrier following the teacher education programme, e.g. limited knowledge of teaching by inquiry. Not being comfortable or confident assessing inquiry is an intrinsic and key challenge which should be tackled in future pre-service teacher education programmes. It is important that teacher's feel confident and competent in both teaching through inquiry and assessing inquiry learning in their classroom (Finlayson, McLoughlin, & McCabe, 2015).

References

Anderson, R. D. (2007). Inquiry as an organising theme for science curricula. In Abell, & Lederman (Eds.), *Handbook of research on science education* (pp. 807 - 830). Mahwah, NJ: Lawrence Erlbaum Associates.

Arce, C., & Garling, T. (1989). Multidimensional Scaling. *Anuario De Psicologia, 43*(4), 65 - 80.

Colburn, A. (2000). An Inquiry Primer. *Science Scope*, 42 - 44.

Crawford, B. A. (2000). Embracing the Essence of Inquiry: New Roles for Science Teachers. *Journal of Research in Science Teaching, 37*(9), 916 - 937.

ESTABLISH. (2014). *ESTABLISH*. Retrieved from www.establish-fp7.eu: http://www.establish-fp7.eu/project

Finlayson, O., McLoughlin, E., & McCabe, D. (2015). Strategies for the Assessment of Inquiry Learning in Science (SAILS) A European Project in Science Teacher Education. *New Perspectives in Science Education* (pp. 225 - 229). Florence: Libreria Universitaria.

Hammer, D. (1997). Discovery Learning and Discovery Teaching. *Cognition and Instruction, 15*(4), 485 - 529.

Hong, J., & Vargas, P. (2016). Science Teachers' Perceptions and Implementation of Inquiry-Based Reform Initiatives in Relation to their Beliefs and Professional Identity. *International Journal of Research Studies in Education, 5*(1), 3 - 17.

Jackson, D. K., & Boboc, M. (2008). Facilitating an Inquiry-Based Science Classroom. *Science Scope, 31*(5), 64 - 67.

Jaworska, N., & Chupetlovska-Anastasova, A. (2009). A Review of Multidimensional Scaling (MDS) and its Utility in Various Psychological Domains. *Tutorials in Quantitative Methods for Psychology, 5*(1), 1 - 10.

Joyce, B., & Showers, B. (1980). Improving Inservice Training: The Messages of Research. *Educational Leadership, 37*(5), 379-385.

Joyce, B., & Weil, M. (1986). *Models of teaching* (3rd Ed. ed.). Eaglewood Cliffs, NJ: Prentice Hall.

Kruskal, J. B. (1964). Multidimensional Scaling By Optimizing Goodness of Fit to a Nonmetric Hypothesis. *Psychometrika, 29*(1), 1 - 27.

Lehman, J. D., George, M., Buchanan, P., & Rush, M. (2006). Preparing Teachers to Use Problem-centred, Inquiry-based Science: Lessons from a Four-Year Professional Development Project. *Interdisciplinary Journal of Problem-Based Learning, 1*(1), 76 - 99.

Linn, M. C., Davis, E. A., & Bell, P. (2004). Inquiry and Technology. In M. C. Linn, E. A. Davis, & P. Bell (Eds.), *Internet Environments for Science Education* (pp. 3-27). Mahwah: Laurence Erlbaum Associates.

Minner, D. D., Levy, A. J., & Century, J. (2010). Inquiry-Based Science Instruction - What is it and Does it Matter? Results from a Research Synthesis Years 1984 to 2002. *Journal of Research in Science Teaching, 47*(4), 474 - 496.

National Committee on Science Education Standards and Assessment, National Research Council . (1996). *National Science Education Standards.* Washington DC: National Academy Press.

National Research Council (NRC). (2000). *Inquiry and the National Science Education Standards: A Guide for Teaching and Learning.* Washington, D.C.: National Academy Press.

Roehrig, G. H., & Luft, J. A. (2004). Constraints Experienced by Beginning Secondary Science Teachers in Implementing Scientific Inquiry Lessons. *International Journal of Science Education*, *26*(1), 3 - 24.

KNOWLEDGE BASE ENLARGEMENT OF A PRE-SERVICE CHEMISTRY TEACHER IN THE CONTEXT OF A BRAZILIAN INITIAL TRAINING PROGRAM

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Abstract: In the literature, there are many proposals for the knowledge needed to become a teacher. Among these, the model of Grossman's teacher knowledge base proposes the subject matter knowledge, general pedagogical, context and pedagogical content knowledge (PCK). For the development of such knowledge the experience in the classroom during the initial training plays a relevant role. In this sense, one of the Brazilian government's actions does its part to provide such teaching experience. The Institutional Program Grant to Teaching Initiation (IPGTI) provides scholarships to undergraduate student teachers to develop projects in public schools and have varied experiences in the classroom before graduating. In this paper, we investigate one chemistry student teacher enrolled in this program. We analyzed two lessons of this student teacher on the content of redox reactions given to a senior class at the school that serves youth and adults students under the supervision of a university teacher and of the teacher class at school. Classes and supervisory meetings were audio/visual recorded and were fully transcribed. Content analysis was performed using the categories of the Grossman's teacher knowledge model. The data revealed that during the first class only the subject matter knowledge and context knowledge appeared, while in the second class it was observed beyond this knowledge, elements of pedagogical content knowledge and pedagogical knowledge. The evolution presented by the student teacher was associated with the outcome of the process developed with the supervision related to the preparation and conduction of teaching classes, the adoption of new strategies in line with the instructional needs of students, among others. This research provides significant evidence of IPGTI project's contribution in the development of the knowledge base of the student teacher and provides positive extrapolations for the development of teachers'knowledge, which the IPGTI project may be providing even through initial training of chemistry teachers.

Keywords: Pre-service science teacher, redox reaction, teachers' knowledge base

Basic knowledge and Initial Teacher Training

In the literature there are several authors (Shulman, 1986, 1987; Grossman, 1990; Carter, 1990; Barnett & Hodson, 2001; Abell, 2007) dealing with the knowledge necessary to be a teacher. In this paper we relied up on Grossman, who proposed a model for the knowledge base necessary for teachers, shown in Figure 1.

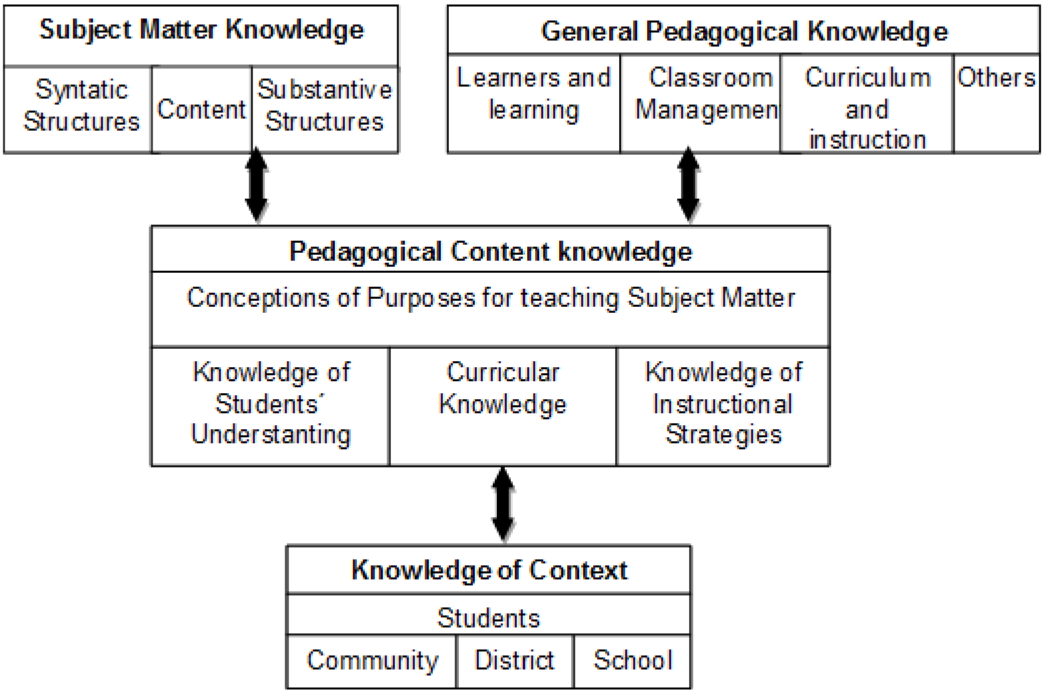

Figure 1. Model of Teacher Knowledge (Grossman, 1990, p. 5).

The knowledge base proposal is a body of knowledge developed along the path of life, academic and school of teachers. (Grossman, 1990, Abell 2007, Fernandez, 2014, 2015). Studies show that teacher education has not trained teachers with the content and pedagogical knowledge needed to teach. In an attempt to overcome this gap, the Brazilian federal government regulated the Institutional Program Grant to Teaching Initiation, IPGTI (in Portuguese it is known as PIBID) (Brasil, 2014). The objectives of this program are:

- encourage the training of teachers for basic education, supporting students who choose teaching careers;
- contribute to the enhancement the teaching;
- rise the quality of initial teacher education in the universities, promoting the integration of higher and basic education;
- insert the pre-service teachers in the daily lives of the public education schools, providing them with opportunities to create and share methodological and technological experiences. Also providing opportunities on innovative and interdisciplinary practices who seek to overcome the problems identified in the teaching-learning process;
- improve the quality of academic activities aimed at initial teacher education in undergraduate courses of higher education institutions;
- encourage public schools of basic education to mobilize their teachers as coach of future teachers and making them protagonists in initial training processes for teaching;
- contribute to the articulation between theory and practice necessary for the training of teachers, raising the quality of academic activities in undergraduate courses.

The program assumes the inclusion of student teachers in the schools, providing them with opportunities to create and participate in methodological experiences, technological and didactic practices who seek to overcome the problems identified in the teaching-learning process. (Brasil, 2014). In this program the student teachers have the supervision of an experienced teacher from the school and a coordinator teacher from the university for the development and implementation of teaching sequences. (Saviani, 2012).

In this context, this paper aims to investigate evidence of the knowledge base development a chemistry student teacher inserted into the IPGTI project through classes held that address the topic of redox reactions.

The IPGTI Chemistry-Subproject

The IPGTI project investigated is hold by one institution of teacher education and it is divided into sub-projects related to the different disciplines. The chemistry sub-project is structured based in two approaches: Science, Technology and Society and Inquiry starting with the motivating question about the National Policy on Solid Waste (Brazil, 2010). This policy is a law that proposes national advancement related to inadequate disposal of solid waste. The project execution occurs through meetings with the area coordinator and the student-teachers, in which are defined goals, studies, benchmarks, guidelines on development activities, actions at the partner schools, etc.

The investigated IPGTI-chemistry project is composed by a coordinator of the undergraduate faculty board in chemistry, two experienced teachers supervisors at public high schools and eleven chemistry student-teachers. Their roles in the institutional program are set out in an announcement issued by the higher education institution, which suggests that the coordinator select supervisors at schools and the student teachers. Both receive a scholarship to work in the program. Within the IPGTI undergraduates are organized in pairs or groups of three to develop their projects in the school field, which in our study is a regular high school and another school that serves youth and adults.

Undergraduate student in chemistry participant of IPGTI

In our study we investigated a chemistry student teacher of this program, which for ethical reasons we call Melissa. The student-teacher had their training in basic education held in a private educational institution. Their entry into the undergraduate occurred in 2014 at 17 years old, and the choice of degree in chemistry was related to his discovery that was the subject she liked best in basic education. (Semi-structured interview, Melissa). According to Melissa a profile for teaching always had been present in his life. She reports that even in high school, whenever possible sought to help his classmates, about the content of the chemistry discipline.The motivations that led her to participate in the IPGTI can be understood in the following stretch:

"Actually I was ordered to participate on IPGTI, someone told me: 'Oh, it's good, go there, right? And I came this way, I had little idea what was going to happen, ah, go there that it is good." (Semi-structured interview, Melissa – turn/round 19).

This speech suggests she did not know the institutional program before but she decided to make the application in the selection of scholarship, she considered a way to be developing activities beyond the course subjects.

Melissa joining IPGTI the same year she joined the teacher education course, his early start in this program may be important in structuring knowledge of teachers still in their initial training.

Methodology

The adopted methodology is qualitative, a case study type (Yin, 2010). Our investigated teacher is a chemistry student teacher in the first year participating in the teaching program IPGTI-Chemistry subproject. In this subproject the student teachers work under the coordination of a chemistry teacher at the university and a supervision of an experienced school teacher.

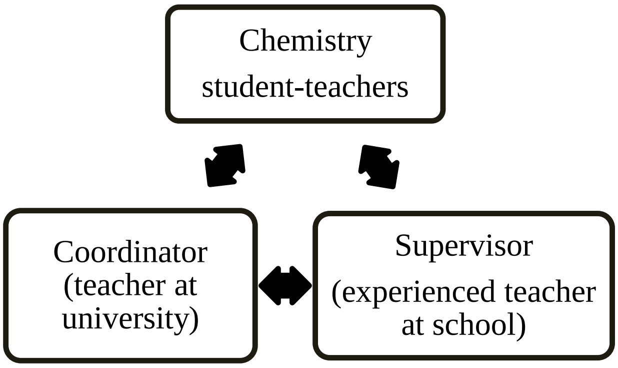

Figure 2. Structure of the IPGTI-Chemistry subproject.

The teachers prepare their lessons with the guidance of the project coordinator, who help in the selection of chemical contents, in the proposition of exercises and choice of teaching strategies. During the implementation of classes by the student teachers they count on the teacher in the classroom. The teaching sequences were structured through STS (Science, Technology and Society) and Inquiry approaches, having as a motivating question the inadequate destination of waste. Data collection occurred by audiovisual records of two regencies, about the same content, redox reactions. The first regency was also the first class taught by our investigated student-teacher and aimed to work on the redox reactions content in a context of the lead contamination by improper disposal of batteries. Therefore, the class related to the redox content, addressed the concepts: definition of oxidation and reduction, species that tend to receive and donate electrons, cathode and anode, the flow of electrons in a redox reaction, balancing redox reactions, number of oxidation (Nox), semi reactions and global reaction. After this first regency the student teacher attended a meeting with the project coordinator to present the structure of the second regency, which permeated a review of the content on redox reactions revision and batteries, in which the ultimate goal was an inquiry lesson on the Daniel battery. Between the two classes there was a gap of forty-five days. The transcripts were subjected to content analysis using the *a priori* categories of teachers' knowledge model (Figure 1).

Results

In the first lesson it was possible to recognize elements of the categories of subject matter knowledge and context knowledge. Some excerpts and its descriptions are displayed in the Table1.

Table 1. Categories of the knowledge base in the first class and description

Category	**Excerpts**	**Class Description**
Subject matter knowledge	[...] Electron is a charge, if a little atom loses electrons, where does it lose it? Can an atom simply lose its electrons? I Lost it? Out of the blue? Does this exist? When anything oxidize, another has to reduce, always [...] Iron, when it's in the form of ion it can have a 2+ or 3+ charge. Let's charge one with 3+? If it is in a normal state, I need it to be the iron with three positive charges, then how many electrons do I take from it?	The student teacher starts the main theme of the class through a quick review about the definition of ions, after that there is an example on the board of an atom that is losing and another that is gaining electrons. The teacher asks the group who is the cation and who is the anion. As a result the teacher directs the conversation to just a group of students in the class. At the end of the explanation Melissa tells the

	(Excerpt taken from the class). […] We didn't do this through a quiz even if they knew before the class; we normally end up doing this in the classroom, "Have you already learned this?" "Have you already seen this in your life?" "We start throwing around these questions to know where to start, right? But this is made in the classroom." (Excerpt taken from the semi-structured interview).	group that the atom that gains the electrons stay with a negative charge while the one that loses stays with a positive one, it is oxidized. But, when structuring the class through questions and answers that make the students feel coerced and they don't participate. At the end Melissa realized that there should have been more concepts given to the group so they could answer the questions.
Knowledge of context	[…] in the next classes we will start working a little with some reactions (redox reaction)" […] "so for us to be able to work with them, this class will be a review of some chemical concepts that you might have forgotten" […]. (Excerpt taken from the class). […]"due to the reality of our students we try to search for chemistry but more in a social way, less numbers, less formulas, less equations and more things related to their lives right? (Excerpt taken from the structured interview).	Knowing the school which the teacher was supposed to have a scholarship through IPGTI Melissa firstly looked for any resources she might have to work with at the school and the profile of the students. After that, the student teacher who decided to teach the subject of redox to YAE, firstly made a quick review of atomic structure, ions, tendencies in gaining and receiving electrons. Melissa organizes the second part of the class to work with tendencies of gaining and receiving electrons, semi reactions and global reactions. For this, the student teacher organizes in the board many exercises and explains one by one to the class. Always structuring the explanations through questions. After Melissa proposes some exercises about the subject taught in the class and, understanding the level of difficulty of the students, she organizes the class in groups, so that the students can work out the problems in a collaborative way.

In the second class elements of more categories are recognized: subject matter knowledge, pedagogical, pedagogical content knowledge and context knowledge, as can be seen in the excerpts and in the description (Table 2).

Table 2. Categories of the knowledge base in the second class and description

Category	Excerpts	Description
Subject matter knowledge	[...] Positive charges, which means it is (zinc) lost these two electrons, these two electrons we leave them out (the product). This is the semi-reaction of the anode right?! Now let's do the semi reaction with the other (copper), all right?	To explain to the group about the loss of electrons Melissa organized in the board a semi-reaction of zinc, showing the class how the chemical representations are made to oxidize. After, the semi-reaction of copper reduction is explained.
General pedagogical knowledge	[…] I need all of you help to refresh my memory, in the last week you had class what did you guys do?" […] I advise you all to take notes of what I'm going to pass on the board, because you will need this in the future. (Excerpt taken from the class). […] I will return to the question of language put the question of mathematics; I have to make it the closest to them as possible. (semi-structured interview excerpt)	In general, the classes are organized in a traditional approach divided into logical sequences and fixed exercises. The student teacher understood that the interactions with the class is made possible through questions using a language accessible to students on the previous session, because she believes that when the students answered correctly there will be more value and they will have the perspective that they are able to learn chemistry, which in the concept of the student teacher is very hard.
Pedagogical content knowledge	[...] Guys, zinc, what happens to it? The process of rusting is happens what? It's in the oxidation process, what will happen to it? [...] Remember the first lesson that I said: Oxidation is the act of? [...] What happens to their electrons? [...] This is not another wire, here is the salt bridge. (Excerpt from the lesson) [...] Classes are more **"quimiques"** (chemical language) even if, I always try to talk to them, and get as close as possible to the reason why. Sometimes, I think, no matter how simple, but the simplest is understandable, then the simplest I can leave, and talk to them all the time, I find it is boring those classes that the teacher keeps talking and everyone just looking, the more I can talk the better.	This passage reveals an informal assessment of the teacher to identify what students had learned in the first class. And the fact that the students have answered correctly gave her a greater security to conduct the class. Melissa replaced as a strategy in the class to explain the content, and then encourages the students to respond, the student teacher also happens to stimulate students to participate in the class by asking them to draw the battery structure on the board, Melissa gives some elements so the students can finish the scheme.

	(Excerpt taken from the class).	
Knowledge of the context	[...] The study goal from the next class will be lead batteries. Why did I have to show this all to you? Nothing fairer than understand how the lead battery works before I start talking about it, right? Batteries are cells in series as Felipe already well said, that over there we can consider as a battery because they are two cells in series. (Excerpt of class) [...] And, for example, it is ... the lead is what is important for our work, we work with lead like this, the question of, the chemical question of teaching lead yes, but it is much more related to their lives, understand? The reason why lead is heavy metal, so it will cause many types of disease, such as from nature, things like social and (unintelligible), as chemistry acts so much in this.” (Excerpt taken from the class).	In the region of the headquarters of the school there are many automobile garages, which dispense material inadequately. In the perception of the student teacher, this problem would be a great way to connect the chemistry student, through a real life situation. So, Melissa structured the classes in a way that the student could understand the subject and the structure of a battery, for afterwards understand the way it works and start to understand the factors that pollutes the rivers, air and earth. Even though this clarity, Melissa didn’t clarify to the students the purpose to develop the redox subject which was linked to lead contamination problems surrounding the school, the improper disposal of batteries

Melissa argues that after the structuring of their classes [...] it has to be evaluated by both the supervisor and the coordinator, rarely we arrive to a class without any of them are there, there is that thing of professional growth, that we see, and look, so here it’s not okay, so here it is senseless, it is too big, too bad, there is always help [...]. (Semi-structured interview excerpt)

Discussion

After analyzing the lessons of this student-teacher, we can notice a gap between the first and second class. In the first performance in the classroom, Melissa revealed evidence relating to two of the categories of the Grossman model, content knowledge and knowledge of the context as we can see at table 1. The student-teacher demonstrated knowledge of the subject redox reactions due to the selection of appropriate content to a high school senior level of knowledge. However there was difficulty to explain the content during the regency because Melissa only listed the contents on the board and questioned students about the studied subject, and there were few moments of explaining of the content, which resulted in a low participation of students in the class. In this sense, it is observed that the focus of the student-teacher was the content itself, she paid little attention to the students and consequently to their difficulties and did not consider their previous knowledge despite having appropriate content to the level of adult education.

The limitations of Melissa in the first regency reveal the importance of teacher consider students' prior knowledge, the form that will organize the class, among others.

On the other hand, in the second regency Melissa improves her speech and starts to take into consideration the difficulties of students’ learning in relation to the concept of redox reactions (table 2). To this end, she begins to choose new ways of teaching, adopting a strategy to integrate students to her class, misconceptions raised about oxidation and reduction reactions.

The second moment is revealing that her class is no longer based only on questioning students but about priorities. Table 2 shows some representative excerpts that reveal an expansion of Melissa's understandings of his actions in the classroom. These observations lead us to infer that the student-teacher has greater certainty about the content and the manner of conducting the class, as the first class she did not instruct students about the activities to be developed. In this second lesson, Melissa reveals elements of all categories of the teacher knowledge base. Although this improvement to other base knowledge categories, these needed to be better structured especially regarding the understanding of the curriculum content and instructional strategies.

We believe that the basic knowledge emerged by Melissa in her career in IPGTI were strongly influenced by the professional development process that she has been going through this program during meetings with the supervisor about the process of structuring lessons about the choices of teaching strategies, besides working with other student-teachers.

Conclusions

In our research we seek to investigate the access of categories of knowledge base proposed by Grossman, by a chemistry student teacher enrolled on the IPGTI during their experience in this program, based on the content of their lessons, redox reactions. The scenario of our research encourages us to discuss that the student-teachers with scholarships in the institutional program had an evolution of its PCK from the first to the second regency. This expansion was linked to factors such as the experience in the classroom still during early teacher education, the guidance received from supervisors about the content to be taught and adopted teaching approaches and their commitment to their actions in this teaching program. Melissa has faced some difficulties in organizing the class, in making use of both analogies and teaching strategies that could have improved her didactic action. These difficulties can be explained by their lack of experience in the classroom since she is a student of first year undergraduate. It is important to highlight from our findings that the IPGTI has been a significant area of training for chemistry teachers in initial education therefore has enabled Melissa started to build the knowledge base at the beginning of her teacher education.

Acknowledgement

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References

Abell, S. K. (2007). Research on science teacher knowledge. *Handbook of research on science education*. 1105-1149.

Barnett, J. & Hodson, D. (2001). Pedagogical Context Knowledge: Toward a fuller understanding of what good science teachers know. *Science TeacherEducation*, 84(4), 426-453.

Brasil. (2014). Capes. *Programa Institucional de Bolsas de Iniciação à Docência* (PIBID). Brasília, DF. Retrieved december 04, 2014, from http://www.capes.gov.br/educacao-basica/capespibid.

Brasil. (2010). *Lei n° 12.305. de 2 de agosto de 2010. Politica Nacional dos Resíduos Sólidos - PNSR*. Retrieved december 04, 2014, from http://www.planalto.gov.br/ccivil_03/_ato2007-2010/2010/lei/l12305.htm.

Carter, K. (1990). *Teachers' knowledge and learning to teacher*. In W. R. Houston (Ed.), Handbook of Research on Teacher Education. New York: Macmillan, 291–310.

Fernandez, C. (2014). Knowledge base for teaching and Pedagogical Content Knowledge

(PCK): some useful models and implications for teachers training. *Problems of Education in the Twenty First Century*, 1, 60, 79-100.

Fernandez, C. (2015). Revisitando a base de conhecimentos e o Conhecimento Pedagógico do Conteúdo (PCK) de professores de ciências. Ensaio: Pesquisa em Educação em Ciências (Online), 17, 500-528.

Grossman, P. (1990). *The making of a teacher: teacher knowledge and teacher education*. New York: Teachers College Press.

Shulman, L. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher*, 15, (2), 4-14.

Shulman, L.(1987). Knowledge and teaching: foundations of the new reform. *Harvard Educational Review*, 57, (1),1-22.

Saviani, D. (2012). PIBID: promoção e valorização da formação docente no âmbito da Política Nacional de Formação de Professores. *Revista Brasileira de Pesquisa sobre a Formação de Professores*, 4(6), 23-43.

Yin, R.K. (2010). *Estudo de caso: planejamento e métodos*. Tradução Ana Thorell; revista técnica Cláudio Damacena. 4º ed. Porto Alegre; Bookman.

MEASUREMENT INVARIANCE AS A VALIDITY ARGUMENT OF A PHYSICS TEACHING EFFICACY QUESTIONNAIRE

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Abstract: There is an ongoing discussion about an appropriate level of specificity in measuring science teachers' efficacy beliefs. As part of a larger project a new questionnaire was developed to measure physics teachers' efficacy beliefs for planning and conducting physics lessons in four fields of action (e.g., dealing with students' conceptions). Thus, a medium level of specificity is addressed. Within the framework of the validation process several (pilot) studies were conducted. The part of the final cross-sectional study (n=931) described below focuses on unidimensionality of the scales and measurement invariance across the groups of pre-service as well as in-service teachers. A confirmatory factor analysis approach was used and results strongly suggest construct validity. Furthermore, an analysis of the mean structure supports the hypothesis of the so-called "reality shock" described in literature. That fact that the instrument allows to detect theoretically expected findings adds to an overall validity argument.

Keywords: teachers' self-efficacy beliefs, professional development, instrument development, validation

INTRODUCTION

The construct of teachers' self-efficacy refers to "the teacher's belief in his or her capability to organize and execute courses of action required to successfully accomplish a specific teaching task in a particular context" (Tschannen-Moran, Woolfolk Hoy, & Hoy, 1998, p. 233) and is considered as a core component of (pre-service) physics teachers' professional development (Lumpe, Vaughn, Henrikson, & Bishop, 2014). Grounded in Banduras social cognitive theory (Bandura, 1997) a lot of research has been conducted over the last decades – concerning both theoretical framework (e.g. Tschannen-Moran et al., 1998) and construct measurement (e.g. Dellinger, Bobbett, Olivier, & Ellett, 2008; Pruski et al., 2013).

The main theoretical issues of interest have been the forming and development of teachers' efficacy beliefs as well as sources for reinforcement or changes in self-efficacy. In particular, the so-called "reality shock" – a decreasing of self-efficacy beliefs after first teaching experiences – is well documented (Woolfolk Hoy, Hoy, & Davis, 2009; e.g. Woolfolk Hoy & Spero, 2005). Regarding measurement issues (e.g., prediction accuracy) current discussions focus on the question of an appropriate level of specificity, but also on the validity and reliability of existing measures (Cakiroglu, Capa-Aydin, & Woolfolk Hoy, 2012). The need for a valid instrument, measuring (science) teachers' self-efficacy beliefs, is clearly stated as a research desideratum in the literature. Since existing measures usually are an adapted or specified version of the Teacher Efficacy Scale (Gibson & Dembo, 1984) some researchers even suggest: "Rather than attempting to revamp a scale, it might be better to go back to the "master" and begin again" (Pruski et al., 2013, p. 1151).

Referring to the above sketched state of research a questionnaire was developed stepwise aiming to measure physics teachers' efficacy beliefs on a precisely defined level (planning and conducting physics lessons). The study outlined in this proposal is embedded into a larger project (compare figure 1) addressing the general research question on both reliability and validity of the newly developed instrument.

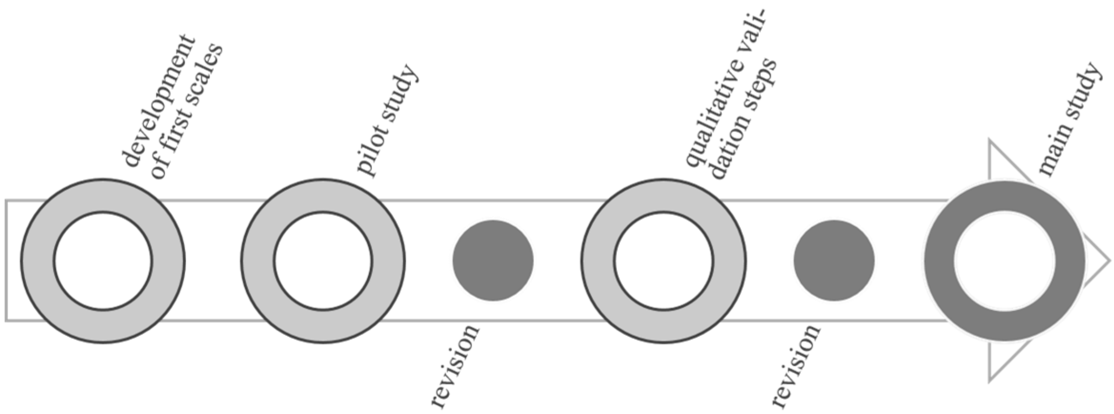

Figure 1: Steps of the validation process from 2011 to 2015.

STUDY DESIGN

For the questionnaire scales (up to ten items) were carefully developed covering four areas of action (“experimenting” (ex), “analysing and preparing physics content” (pc), “dealing with tasks” (dt) and “dealing with students’ conceptions” (sc). Each field of action is subdivided into the dimensions “planning” (-p) and “conducting” (-c). For details of the item development process or construction rules see Meinhardt, Rabe, & Krey (2014). Table 1 presents selected item examples, which have been translated into English for the purpose of this article. However, the instrument was tested and revised in German language and with German (pre-service) teachers. Therefore all of the results presented below refer to the German version of the instrument.

Table 1. Item examples for each field of action and each dimension.

scale	item example
pc-p	I can simplify a physics topic comprehensively when planning a teaching unit, even when it deals with topics of the modern physics.
pc-c	I can conduct a physics lesson in a structured order, even when I have to adjust my approach spontaneously to the questions of my pupils.
dt-p	I can develop a task, which enables the pupils to understand a physics content independently, even when the topic is difficult for them.
dt-c	I can support my pupils in the physics lessons when working on the physics tasks, without merely providing a step by step guidance or the solution altogether.
sc-p	I can plan a physics lesson which sets the pupils’ everyday conceptions as a starting point for the learning process, even when they are contradictory.
sc-c	I can spontaneously provide suitable examples which motivate the pupils to question their everyday conceptions, even when they are very convinced by them.
ex-p	I can prepare experiments matching the learning objectives, although the school lab is not equipped well.
ex-c	I can conduct a demonstration experiment comprehensively, even if the experimental setup is rather complex.

Several (pilot) studies for validation purposes have been conducted so far in the framework of a mixed methods approach (expert ratings, think aloud, interviews, confirmatory factor analysis). Results have been positive und support the validity argument (for details see e.g. Meinhardt, Rabe, & Krey, 2014).

Within the cross-sectional main study of the project described below we look into questions of unidimensionality of the scales, the distinction between the two dimensions “planning” and “conducting”, correlations to other constructs (for analysis of discriminant validity) and the measurement invariance across groups. Also whether the instrument enables the detection of theoretical expected finding (e.g., designated “reality shock”) is of interest in terms of construct validity. Not all of the mentioned aspects can be outlined in this paper.

SAMPLE AND METHOD

From October 2013 to April 2014 altogether 931 participants were surveyed (n=525 physics teacher students, n=238 trainee physics teachers and n=168 in-service physics teachers), ticking off a 6-ary likert scale (1-6).

In a first step a confirmatory factor analysis (CFA) is done for each of the scales in each area of action and for each group using Mplus software (Muthén & Muthén, 2012). Since data is non-normally distributed and contains missings (circa .02 %) a robust maximum likelihood (MLR) estimator is used. Data is analysed as continuous here. Modell fit is evaluated by common criteria such as factor loadings >.5, χ^2/df<2.0, CFI>.95, TLI>.95, RMSEA<.05, SRMR<.05 (e.g. Hu & Bentler, 1999; Schermelleh-Engel, Moosbrugger, & Müller, 2003).

In another step the measurement invariance is tested based on the mean structure (MACS) within a multi group analysis. Nested models are compared by a χ^2-difference test (Satorra-Bentler scaled χ^2-value). The MACS procedure includes testing the equivalence of latent factor means, whereas only mean differences can be analysed. Further, the CFA approach enables to test whether a second-order structure can be found in the data.

RESULTS

Table 2 shows the descriptive statistics of the scales for each participant group. Also a first CFA of each scale and for each group is conducted. Taking into consideration the results of these analyses scales are subject to minor revisions in terms of excluding single items (but only if content related arguments are available). The in such way revised scales are re-examined through another CFA. Goodness-of-fit results are satisfying (table 3).

Table 2. Descriptive statistics of the scales.

	students					trainee teachers					in-service teachers				
	mean	s.e.	sd	min	max	mean	s.e.	sd	min	max	mean	s.e.	sd	min	max
pc-p	4.18	.03	.71	1.63	6.00	4.14	.05	.79	1.25	5.88	4.73	.05	.61	2.38	6.00
pc-c	4.21	.03	.75	1.33	6.00	4.06	.05	.76	1.50	6.00	4.86	.05	.62	2.67	6.00
dt-p	3.91	.03	.69	1.38	5.88	3.74	.05	.80	1.38	5.50	4.33	.06	.73	1.88	5.88
dt-c	4.17	.03	.65	1.75	5.75	4.04	.04	.68	1.38	5.50	4.66	.04	.56	2.88	5.88
sc-p	4.12	.03	.72	1.57	6.00	3.96	.05	.77	1.33	6.00	4.52	.05	.71	1.43	5.86
sc-c	4.10	.03	.75	1.50	5.83	4.04	.05	.74	1.50	6.00	4.85	.05	.66	2.33	6.00
ex-p	4.01	.03	.77	1.00	5.88	3.93	.05	.78	1.25	5.63	4.42	.06	.78	1.88	6.00
ex-c	4.19	.03	.74	1.00	5.88	4.14	.05	.76	1.50	5.75	4.67	.06	.72	2.00	6.00

The reported models (baseline models) of table 3 are the starting point for invariance testing, based on the established configural invariance. To sum up, (partial) measurement invariance across the three groups (physics teacher students, trainee physics teachers and in-service physics teachers) can be verified for each scale. In table 4 results of the invariance test for the sc-c scale (self-efficacy beliefs concerning the dealing with students’ conceptions/conducting) are shown as an example.

Table 3. Results of a CFA for revised scales in each group (s: students, tt: trainee teachers, it: in-service teachers).

		χ^2	df	χ^2/df	p	CFI	TLI	RMSEA [90% CI]	SRMR
pc-p	s	40.68	20	2.03	.004	.978	.969	.044* [.024; .064]	.030
	tt	39.05	20	1.95	.007	.958	.941	.063* [.033; .093]	.040
	it	19.36	20	0.97	.499	1.000	1.004	.000* [.000; .064]	.038
pc-c	s	21.60	9	2.40	.010	.982	.970	.052* [.024; .080]	.026
	tt	11.02	9	1.22	.275	.992	.987	.031* [.000; .083]	.029
	it	19.679	9	2.19	.020	.951	.919	.084* [.032; .135]	.045
ep-p	s	34.44	20	1.72	.023	.981	.973	.037* [.014; .058]	.027
	tt	45.73	20	2.29	.001	.938	.914	.074* [.045; .102]	.046
	it	26.23	20	1.01	.158	.979	.970	.043* [.000; .084]	.044
ep-c	s	27.39	14	1.96	.017	.981	.971	.043* [.018; .066]	.028
	tt	19.93	14	1.42	.212	.981	.972	.042* [.000; .081]	.034
	it	17.24	14	1.23	.244	.990	.984	.037* [.000; .087]	.033
sc-p	s	21.10	14	1.51	.099	.989	.984	.031* [.000; .057]	.025
	tt	24.20	14	1.73	.043	.973	.959	.055* [.010; .092]	.036
	it	11.29	14	0.81	.663	1.000	1.017	.000* [.000; .061]	.032
sc-c	s	13.57	9	1.51	.139	.993	.988	.031* [.000; .063]	.020
	tt	20.16	9	2.24	.017	.955	.925	.072* [.029; .115]	.039
	it	18.72	9	2.08	.028	.962	.937	.080* [.026; .132]	.038
ex-p	s	49.18	20	2.46	.000	.971	.959	.053* [.034; .072]	.032
	tt	21.61	20	1.08	.362	.995	.993	.018* [.000; 060]	.034
	it	34.90	20	1.75	.009	.954	.935	.073* [.036; .108]	.042
ex-c	s	59.23	20	2.96	.000	.959	.942	.061* [.043; .079]	.035
	tt	29.07	20	1.45	.086	.979	.970	.044* [.000; .076]	.036
	it	40.89	20	2.05	.004	.948	.927	.079* [.044; .113]	.044

Table 5 shows the estimated differences of the latent factor means for the groups of trainee physics teachers (tt) and in-service physics teachers (it) compared to the latent factor means for the physics teacher students (s, reference group) as a result of the CFA multi group analysis. A characteristic of this method is that the latent factor means for the reference group are always constrained to zero. Therefore positive values in the estimate column (table 5) indicate stronger self-efficacy beliefs for the groups of interest compared to teacher students group. A negative estimate indicates a lower scale mean for the considered group in comparison to the teacher students.

Table 4. Tests for invariance of the sc-c scale across the three groups: summary of model fit and χ^2-difference-test statistics, * intercept of one item (scc2) was estimated freely.

invariance model	χ^2	df	p	CFI	RMSEA	SRMR	model comparison	ΔSB- χ^2	df	p	|ΔCFI|
configural (1)	52.67	27	.00	.977	.055	.030					
metric (2)	66.94	39	.00	.975	.048	.080	1 vs. 2	13.93	12	.31	.002
scalar (3)	97.20	49	.00	.957	.056	.095	2 vs. 3	32.44	10	.00	.018
scalar* (4)	77.08	47	.00	.973	.045	.078	3 vs. 4	24.42	2	.00	.016
							4 vs. 1	23.48	20	.27	.004

The means of four scales (pc-c, dt-c, sc-p, ex-p) are significantly lower for the trainee teachers than the means of the scales for the student group. This tendency is also found for the dt-p and sc-c scales. Finally, there are two scales (pc-p, ex-c) without a mean difference between the groups. Comparing students with in-service teachers one can find that the latent factor means of the in-service teachers are always significantly higher.

Detailed results are not presented here, but when changing the reference group one can add that the mean differences of trainee and in-service teachers always differ significantly in the way that the latent factor means of in-service teachers are estimated to be higher than the latent factor means of the trainee teachers.

Table 5. Mplus output: differences of latent factor means of the trainee teachers (tt) and the in-service teachers (it) compared to the latent factor mean of the reference group (student, s).

factor/scale	group	estimate	SE	estimate/SE	p
pc-p	tt	.017	.102	.165	.87
	it	.936	.099	9.413	.00
pc-c	tt	-.228	.092	-2.471	.01
	it	1.019	.094	1.824	.00
dt-p	tt	-.181	.094	-1.920	.06
	it	.607	.109	5.556	.00
dt-c	tt	-.288	.101	-2.853	.00
	it	.564	.104	5.424	.00
sc-p	tt	-.285	.092	-3.104	.00
	it	.569	.102	5.562	.00
sc-c	tt	-.158	.090	-1.745	.08
	it	1.082	.105	1.330	.00
ex-p	tt	-.242	.092	-2.632	.00
	it	.449	.107	4.189	.00
ex-c	tt	-.021	.090	.299	.82
	it	.841	.105	8.020	.00

DISCUSSION AND CONCLUSION

The results support the assumption that the developed items constitute unidimensional scales with respect to each area of action, each dimension and each participant group (physics teacher students, physics trainee teachers, and in-service physics teachers). Further, tests of measurement invariance indicate that the scales measure the same latent constructs across the three groups. In combination with our qualitative pilot studies we are confident, that the intended constructs are measured indeed. Finally, the latent mean analysis supports the hypothesis of the “reality shock” taking into account the fact that the study is cross-sectional. In summary there is quite some evidence for construct validity.

OUTLOOK

More detailed analysis have been done for example considering measurement invariance for several subgroups (e.g. male vs. female) or in terms of correlation analysis. For cross validation purposes and a deeper insight into the functioning of the rating scale a Rasch analysis was conducted. When combining all the results the assumption of a valid instrument seems to be reasonable. Nevertheless it should be stressed that the instrument was piloted and validated in German language in a German cultural landscape. After finishing the remaining analysis a comprehensive scale report will be provided in German.

REFERENCES

Bandura, A. (1997). *Self-Efficacy. The Exercise of Control*. New York: W. H. Freeman & Company.

Cakiroglu, J., Capa-Aydin, Y., & Woolfolk Hoy, A. (2012). Science Teaching Self Efficacy Beliefs. In B. J. Fraser, K. G. Tobin, & C. J. McRobbie (Eds.), *Second International Handbook of Science Education* (pp. 449–462). Dordrecht, Heidelberg, London, New York: Springer.

Dellinger, A. B., Bobbett, J. J., Olivier, D. F., & Ellett, C. D. (2008). Measuring teachers' self-efficacy beliefs: Development and use of the TEBS-Self. *Teaching and Teacher Education*, *24*, 751–766.

Gibson, S., & Dembo, M. H. (1984). Teacher Efficacy: A Construct Validation. *Journal of Educational Psychology, 76*(4), 569–582.

Hu, L., & Bentler, P. M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Structural Equation Modeling: A Multidisciplinary Journal, 6*(1), 1–55.

Lumpe, A., Vaughn, A., Henrikson, R., & Bishop, D. (2014). Teacher Professional Development and Self-Efficacy Beliefs. In R. Evans, J. Luft, C. Czerniak, & C. Pea (Eds.), *The Role of Science Teachers' Beliefs in International Classrooms. From Teacher Actions to Student Learning* (pp. 49–64). Rotterdam: Sense Publishers.

Meinhardt, C., Rabe, T., & Krey, O. (2014). Pre-service teachers' self-efficacy beliefs for teaching physics. In C. P. Constantinou, N. Papadouris, & A. Hadjigeorgiou (Eds.), *E-Book Proceedings of the ESERA 2013 Conference: Science Education Research For Evidence-based Teaching and Coherence in Learning. Part 13 (co-eds. L. Avraamidou & M. Michelini)* (pp. 244–250). Nicosia, Cyprus: ESERA.

Muthén, L. K., & Muthén, B. O. (2012). *Mplus. User's Guide* (7th Ed). Los Angeles, CA: Muthén & Muthén.

Pruski, L. A., Blanco, S. L., Riggs, R. A., Grimes, K. K., Fordtran, C. W., Barbola, G. M., … Lichtenstein, M. J. (2013). Construct Validation of the Self-Efficacy Teaching and Knowledge Instrument for Science Teachers-Revised (SETAKIST-R): Lessons Learned. *Journal of Science Teacher Education, 24*(7), 1133–1156.

Schermelleh-Engel, K., Moosbrugger, H., & Müller, H. (2003). Evaluating the Fit of Structural Equation Models: Tests of Significance and Descriptive Goodness-of-Fit Measures. *Methods of Psychological Research Online*, *8*(2), 23–74.

Tschannen-Moran, M., Woolfolk Hoy, A., & Hoy, W. K. (1998). Teacher Efficacy: Its Meaning and Measure. *Review of Educational Research*, *68*(2), 202–248.

Woolfolk Hoy, A., Hoy, W. K., & Davis, H. A. (2009). Teacher's Self-Efficacy Beliefs. In K. R. Wentzel & A. Wigfield (Eds.), *Handbook of Motivation at School* (pp. 627–653). New York: Routledge.

Woolfolk Hoy, A., & Spero, R. B. (2005). Changes in teacher efficacy during the early years of teaching: A comparison of four measures. *Teaching and Teacher Education*, *21*(4), 343–356.

MEDIA AS A TEACHING RESOURCE IN BIOLOGY CLASSES: UNDERGRADUATES' EXPERIENCES

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Abstract: Currently biological questions as Genetically Modified, stem cells, vaccines, new medicines and genetic research are widely disseminated in society through the media. This work represents a step in a master's research already completed about pre-service teacher education within the context of the Programa Institucional de Bolsas de Iniciação à Docência (PIBID) and aims to investigate how Biology undergraduates planned and developed didactical sequences using the media as a teaching resource. For analytical framework, we used content analysis. The corpus of this research was composed by twenty-one plannings of didactical sequences, eleven questionnaires and nineteen reports, all from the investigated undergraduates. The data indicate that the undergraduates who participated of PIBID project evaluated the use of media in Biology classes as a tool to contextualize the content taught, aiming at a meaningful learning of students. However, we found that the undergraduates still have to work more the media critical reading, and perform more differentiated activities when plan the use of printed media. It is very significant that future teachers learn how to use and how to accomplish media critical reading, because teachers should develop the capacity to evaluate how students interpret media messages and information from a variety of sources. We highlight the need for greater investment in research on the use of media in science education and a large deepening about the topic in pre-service science teacher education.

Keywords: Media, Biology education, pre-service teacher education, media critical reading.

INTRODUCTION

This work represents a step in a master's research already completed about pre-service teacher education within the context of the Programa Institucional de Bolsas de Iniciação à Docência (PIBID). PIBID is a Federal program created in 2007 by CAPES (Coordenação de Aperfeiçoamento de Pessoal de Nível Superior) which aims to promote the initiation to teaching and contribute to improving the quality of Brazilian public basic education.

We investigated participants of PIBID program of Universidade Federal do ABC (UFABC), located in São Paulo – Brazil. The propose of PIBID/UFABC is promote for the Biology undergraduates real teaching and learning experiences at a public schools of basic education, the construction of an investigative and reflective look and the planning and application of didactical sequences which explore the biological content, using media as a teaching resources (UFABC, 2010).

Preliminary results of this analysis were published in Faustino & Silva (2013) and, therefore, this work aims to contribute to the discussions established about the use of media in Biology education, from a pre-service teacher education program.

Those Biology undergraduates who participate PIBID´s project, need to use media from magazines, newspapers, television programs, radio and internet, as teaching resources to build their didactical sequences, and then apply it at public schools of basic education associated with the program.

Detjen (1995) already indicated that the role of media in science education was important because the most knowledge that people have about environment comes from newspapers, magazines, radio and television. In addition to that, currently biological questions as

Genetically Modified, stem cells, vaccines, new medicines and genetic research are widely disseminated in society through the media.

About working with media in the classroom, Marandino, Selles & Ferreira (2009) warn that the school culture and its educational interests give new meaning to the media and its use in this context; it is considered a process of recontextualization, to relocate the media and their contents in a proper context, with its goals, directions and specifics.

The use of media in teachers formation is important because teachers should be able to examine and understand how media content and other information are produced, how the information these systems present can be evaluated, and how media and information can be used for different purposes (UNESCO, 2011). In the same way, Becker & Pinheiro Filho (2011) state that through media critical reading the viewer is likely to expand their understanding of the media coverage process, recognize the media as institutions producing meanings about social reality and build their own perceptions of the media and television.

In view of the need for better pre-service teacher education programs and the potential of using media as a teaching resource in the classroom, the question of this study was: how is the use of media in didactic sequences planned for Biology undergraduates who participates in a pre-service teacher education program.

To answer this questions we analysed, using Bardin (1977) content analysis, a *corpus* composed by twenty-one plannings of didactical sequences, eleven questionnaires and nineteen reports, all from the investigated undergraduates. The data indicate that the undergraduates who participated of PIBID project evaluated the use of media in Biology classes as a tool to contextualize scientific content, aiming at a meaningful learning of students. However, we found that the undergraduates still have to practice more the media critical reading, and perform more differentiated activities when plan the use of printed media.

METHOD

A qualitative research interprets the writing, speech, gestures and actions of the research participants (Carvalho, 2006). In this present investigation, the research participants were Biology undergraduates who participated in PIBID/UFABC.

For analytical framework, we used Bardin (1977) content analysis. This author consider that all analysis is realized from a set of documents called *corpus*. The *corpus* of this research was composed by twenty-one plannings of didactic sequences, eleven answered questionnaires and nineteen reports, which are documents that undergraduates write after minister their classes at the public school of basic education, narrating how the lessons happened, some outstanding situations and their critical reflections.

These documents were developed by the undergraduates from August 2010 until May 2013, and for the analysis of the *corpus* we selected analysis units, which are excerpts from the undergraduates ideas. Each analysis unit received a code according to its origin, (P) for plannings (Q) for questionnaires and (R) for reports.

Among the questions answered by the undergraduates, there were two that we focused in this present research:

1. Describe your opinion about using media in the classroom and what are the consequences of this in teaching practice and in the learning process of the students?

2. What Information Sources (IS) listed below you use most often to develop your planning of didactic sequences? (Use always, regularly, occasionally, hardly or never).

IS1	Scientific articles read in degree	IS7	Texts from websites
IS2	Scientific articles unread in degree	IS8	Videos from websites
IS3	Public schoolar material	IS9	Television news
IS4	Textbooks of 1ª and 2º levels	IS10	Newspaper
IS5	Textbooks of higher levels	IS11	Scientific dissemination magazines
IS6	Board daily	IS12	General approach magazines

Bardin (1977) determined that there are two inverse processes of categorization. In the first one, the categories are provided from the theory and theoretical framework. In the second process, the one we used in this investigation, the categories emerged from the analysis of the *corpus*, establishing a more inductive classification process. We will expose, in the next section, the categories used and the main results of this research.

RESULTS

The frequencies of the different sources of information that undergraduates used to build their classes sequences are expressed in Figure 1.

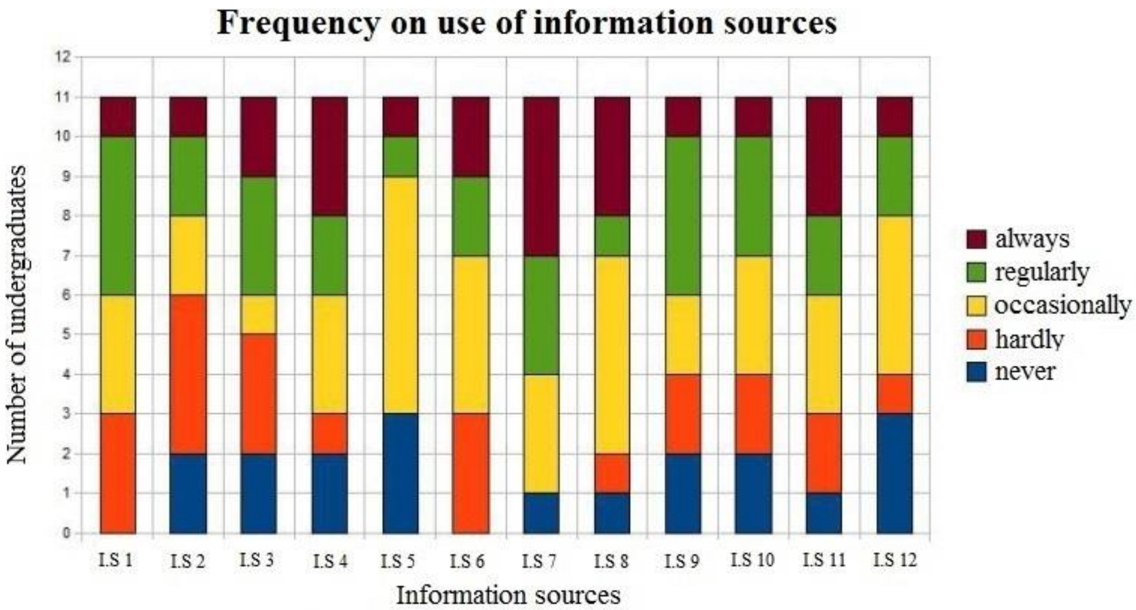

Figure 1. Frequency on use of information sources by undergraduates for planning didactic sequences.

The graph shows that the undergraduates have sought access to a wide variety of information sources to prepare their didactical sequences. Texts from websites received more nominations from "always" used in the preparation of activities. Other highlighted sources were the magazines of scientific dissemination, videos from websites and textbooks of primary and secondary level. All sources of information, at least once, were classified as "always" used in the planning of activities. The sources which are less used are the textbooks of higher level and reports of general approach magazines.

Even when the undergraduates plan to use magazines and newspapers reports on the didactic sequences the access to this material was given almost entirely online, since many newspapers and magazines have their content on the Internet. It happens with the reports of TV channels as well, so the undergraduates could use TV news reports or videos from variety shows. Many other videos were accessed on the website www.youtube.com.

The categories which emerged from the *corpus*, as well examples of analysis units are arranged on Table 1

Table 1. Categories and analysis units.

<table>
<tr><th colspan="3">Categories and Analysis Units</th></tr>
<tr><td colspan="3">Category 1 – Contextualizing</td></tr>
<tr><td colspan="3">Analysis units</td></tr>
<tr><td>"Right now, we intend to pay attention to two texts (magazine) in particular: of the worm diseases and the discovery of penicillin. Both, in a way, are closer to the reality of students ... It is interesting to comment on the presence of these relationships in daily life and in the history of science, such as the discovery of penicillin ... "(P1)</td><td>"The media is important for contextualization of biological knowledge studied in classroom… make them realize that many subjects studied at school are part of everyday life."(Q1)</td><td>“I realized that the media made a key role in illustrating and facilitating interconnections and in parts of explanations relate science to everyday life helped to facilitate student comprehension by bringing content closer the receiver.” (R1)</td></tr>
<tr><td colspan="3">Category 2 - Triggering actions in the classroom</td></tr>
<tr><td colspan="3">Analysis units</td></tr>
<tr><td colspan="2">"... After reading the text, there will be a debate with the students using the following questions: What is sustainable development? What everyday actions may have that effect?" (P2)</td><td>... will be displayed the video "Story of Stuff", with further discussion.” (P3)</td></tr>
<tr><td colspan="3">Category 3 - Complementation of the class content</td></tr>
<tr><td colspan="3">Analysis units</td></tr>
<tr><td>“The magazine media was enlightening and complement the expositive classes.” (R2)</td><td colspan="2">“I believe the printed media used were the basis for the explanation of the content.” (R3)</td></tr>
<tr><td colspan="3">Category 4 – Printed media versus Audio-visual media</td></tr>
<tr><td colspan="3">Analysis units</td></tr>
<tr><td>“Even with the choice of a very short text, with illustrations and easy understanding it was more challenging to avoid the dispersion of students compared to the video displayed minutes before.” (R4)</td><td colspan="2">“I think that working with the television media, with reports, documentaries or movies would have caused even greater student interaction with the subject.” (R5)</td></tr>
<tr><td colspan="3">Category 5 – Media critical reading</td></tr>
<tr><td colspan="3">Analysis units</td></tr>
<tr><td colspan="3">“Practice media critical reading is a ghost activity in my work so far. I believe this is a constant exercise and even for some adults it is difficult. "(Q2)</td></tr>
</table>

As set forth in the Table 1, the undergraduates used the media as a way to engage the daily lives of students, contextualize scientific and biological contents, trigger actions in the classroom such as debates and discussions and they believe the media are a great tool to complement the content of the lessons. Furthermore, students associated the use of audio-visual media with student's greater attention and performance; they indicated the involvement and student achievement after viewing a video or television report was higher when compared to printed media.

About media critical reading, we find that the undergraduates found it difficult to exercise critical media reading, so they still have to propose more activities which seek to identify what is behind the issues related in newspapers, magazines and television. In the next section, we will briefly discuss the results and expose our conclusions.

DISCUSSION AND CONCLUSIONS

The data indicate that the undergraduates who participate in PIBID/UFABC project evaluated the use of media in Biology classes as a tool to contextualize the scientific and biological content, aiming at a meaningful learning of students. When the undergraduates used the media as a teaching resource, the classes become differentiated because many other activities could be developed.

According to Martins, Nascimento & Abreu (2004) texts of scientific dissemination, when used in the classroom, can act as motivators or structural elements of the class, explanations organizers, triggering debate, contexts for the acquisition of new ways of reading, establish links with the daily lives of students, expand them discursive universe and highlight aspects of the scientific practice.

Even with all this potential, undergraduates found that students had difficulties of reading printed media and, therefore, preferred audio-visual ones. For Zia *et al.* (2014) the practice of reading can cause the student estrangement and lack of interest by not being part of their habits, however, the application of this language is extremely important.

We understand that to improve student involvement in these activities, it is essential the association of the printed media reading with a differentiated teaching mode as dynamics or reading groups.

However, the use of audio-visual media is also important. The critical reading of television can assist in building a wider view of the central role of the media today, besides encouraging greater understanding of the meanings of the messages about the social reality and the audio-visual itself as language and way of thinking (Becker & Pinheiro Filho, 2011)

It is very significant for future teachers learn how to use and how to accomplish media critical reading, because teachers should develop the capacity to evaluate how students interpret media messages and information from a variety of sources (UNESCO, 2011)

Although it is a task which is little explored by undergraduate, it is necessary to practice media critical reading and start planning didactical sequences that also take this critical reading for students of public basic education schools.

Lastly highlight the need for greater investment in research on the use of media in science education and a large deepening about the topic in pre-service science teacher education.

REFERENCES

Bardin, L. (1977). *Análise de conteúdo*. Lisboa, LX: Edições 70.

Becker, B. & Pinheiro Filho, C.D.M. (2011). No estranho planeta dos seres audiovisuais: diálogos possíveis entre televisão e educação. *Famecos,* 18(2), 490-506.

Carvalho, A. M. P. (2006). Uma metodologia de pesquisa para estudar os processos de ensino e aprendizagem em salas de aula. In: F. M. T. Santos & I. M. Graca (Eds.), *A pesquisa em ensino de ciências no Brasil e suas metodologias*. Ijuí, RS: Editora Unijuí.

Detjen, J. (1995). The medias´s role in Science Education, the public is interested in News about Science and the environment. *BioScience*, (Supplement), S58-S63.

Faustino, M. & Silva, R. (2013). Mídia e ensino de biologia: aspectos de alfabetização científica nos planejamentos de aula construídos por licenciandos. *Enseñanza de las ciências*, extra number.

Marandino, M., Selles, S. & Serra, M. (2009). *Ensino de Biologia: histórias e práticas em diferentes contextos*. São Paulo, SP: Cortez.

Martins, I., Nascimento, T. G. & Abreu, T. B. (2004). Clonagem na sala de aula: um exemplo do uso didático de um texto de divulgação científica. *Investigações em Ensino de Ciências*, 9(1), 95-111.

UFABC. (2010). *Projeto institucional do PIBID UFABC*. Available from https://pibidufabc.wordpress.com/1-projeto-pibid/projeto-integracao-escola-universidade-na-formacao-de-professores-das-ciencias-e-matematica.

UNESCO. (2011). *Media and Information Literacy: Curriculum for Teachers*. Paris, FR: UNESCO.

Zia, I. C. A., Mansani, R. E.C., Lima, R. L., Rufino, M., Miranda, M. A. G. C. & Silva, R. L. F. (2014). O uso da mídia na contextualização de temas biológicos: contribuições para licenciandos e alunos da educação básica. In M. P. Silva, M. A. G. C. Miranda & M. H. Alvim (Eds.*), PIBID/UFABC e o processo ensino-aprendizagem em Ciências e Matemática* (pp. 63-82). Jundiaí, SP: Paco editorial.

EFFECTS OF A SUPERVISED INTERNSHIP ON PRE-SERVICE SCIENCE TEACHERS' SELF-EFFICACY BELIEFS[1]

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Abstract: Self-efficacy beliefs regarding science teaching should already be fostered during pre-service teacher education. One opportunity to change pre-service teachers' self-efficacy beliefs may be through internships in schools; however, the conditions that this change depends on are unclear. In spite of this, pre-service teachers may serve these internships with teachers who themselves possibly have low self-efficacy beliefs regarding teaching science. Thus, the question arises, whether pre-service teachers' self-efficacy beliefs could be fostered through internships supervised by expert teachers trained before.

In the context of the ITPP Project (**I**ntegration of **T**heory and **P**ractice – **P**artner schools), in-service teachers are trained in primary science education; afterwards they supervise pre-service teachers in their first internship. Nonetheless, places for the ITPP internships are limited, so that further pre-service teachers participate in other internships (non-ITPP). The aim of the study is to examine pre-service teachers' self-efficacy beliefs regarding teaching primary school science after their first internship: Do the pre-service teachers' in the two groups (ITPP; non-ITPP) differ in their self-efficacy beliefs after internship? Preliminary results show that pre-service teachers participating in the ITPP Project scored significantly higher regarding their science teaching self-efficacy beliefs than pre-service teachers not participating in the ITPP Project. However, different features of the internship mediate the relationship between the ITPP Project and self-efficacy beliefs.

Keywords: science teaching in primary school; pre-service teacher education; self-efficacy beliefs

THEORETICAL BACKGROUND AND AIMS

Self-efficacy Beliefs regarding Science Teaching in Primary schools

The self-efficacy beliefs of (prospective) teachers are meaningful for (later) professional practice in teaching and has an influence on student achievement (cf. Ashton & Webb, 1986). Studies have shown, for example, that teachers' self-efficacy beliefs correlate positively with the learning attainment and motivation of pupils (Karstens, 2009). Yet many primary school teachers, especially in science teaching, have little faith in their own abilities (Tonsun, 2000; Möller, 2004). In-service teachers – particularly those with low self-efficacy beliefs and negative previous experiences from their school days (Appleton & Kindt, 2002) – tend to avoid teaching scientific subject matter (Appleton, 2003), as they perceive these issues as too difficult for their own teaching (cf. Mulholland & Wallace, 2000). This 'distance' regarding the sciences is also already exhibited by pre-service teachers (Landwehr, 2002). For this reason, it is important to encourage pre-service teachers in the subject area of primary science education with a special emphasis on self-efficacy beliefs right from the beginning of their studies.

One possibility for fostering pre-service teachers' self-efficacy beliefs during the course of their studies is practical experience. Research studies indicate that self-efficacy beliefs in regard to their one's own science teaching can be supported through positive experiences from real-life practice (Velthuis, Fisser & Pieters, 2014). Likewise, it is possible that the representative experiences of others, through mentoring teachers for example, can be a positive source of change in self-efficacy beliefs (Tschannen-Moran & Woolfolk Hoy, 2007).

Internships as Learning Opportunities in Teacher Education

Pre-service teachers attach great importance to practical phases in their studies (Boekhoff, Franke, Dietrich & Arnold, 2008); likewise, periods of practice are an important element of teacher education in Germany, as the current introduction of an obligatory practice semester demonstrates for instance. The actual effectiveness of practical work in relation to the development of competences is, however, a topic of controversial discussion (e.g., Arnold, Gröschner & Hascher, 2014): On the one hand, pre-service teachers report positive developments in their competencies after a practice phase (e.g., Gröschner, Schmitt & Seidel, 2013). On the other hand, there are also findings that speak about pre-service teachers overestimating their competence following an internship (Schubarth, Gottmann & Krohn, 2014). Regarding changes in self-efficacy beliefs through internships, there are also mixed findings: Velthuis and her colleagues (2014) were able to show that the pre-service teachers' self-efficacy beliefs in science teaching could be raised through practical experiences. In comparison, other studies show however that pre-service teachers' self-efficacy beliefs sink after practice phases (e.g., Lamote & Engels, 2010).

One aspect of the discussion about the effectiveness of practice that is repeatedly emphasized, is the role of the supervising teacher (e.g., Bach, 2013; Staub, Waldis, Futter & Schatzmann, 2014). In this respect, the teacher can be seen as an important reference person during the intership, who can aide pre-service teachers in developing their competencies (Hascher & Moser, 2001; Gröschner & Häusler, 2014). The effectiveness of practice teaching phases appears to depend on the knowledge and personal prerequisites, which the supervising teacher brings to the mentoring situation (e.g., Hascher, 2011; Hascher, 2006; Möller, 2012; Schubarth et al., 2014). Rots and colleagues (2007) showed that the job-specific, self-efficacy beliefs of pre-service teachers related positively to the support that they felt they received through the supervising teachers. In addition, a study by Kreis and Staub (2011) showed that differences in the lesson quality of pre-service teachers during their internships was dependent on the supervision: The experts estimated the lesson quality of the pre-service teachers, who were supervised by specially trained teachers, as higher than the quality of teaching of pre-service teachers, who were supported in the traditional way.

Admittedly, until now there is little empirical evidence that tells us what kind of support from the supervising teacher is possibly appropriate and/or effective (Hascher, 2012). Likewise, it is unclear whether and to what extent supervision during the teaching internship could affect self-efficacy beliefs. This is where the following study to the ITPP Project (**I**ntegration of **T**heory and **P**ractice – **P**artner Schools) picks up, which we will briefly describe here.

The ITPP Project – A Learning Opportunity with a Focus on Science Teaching in Primary Schools

The ITPP Project engages in creating practice-oriented learning opportunities for primary pre-service teachers during their studies by cooperating with specially trained in-service teachers. Through these learning opportunities, the project has, among others, the goal of developing professional competencies of pre-service teachers regarding primary science education, and through this, to positively foster their self-efficacy beliefs in regards to science teaching.

The ITPP Project is a German project, in which in-service teachers of so-called partner schools cooperate with the Institute for Teaching and Learning Primary Science and Technology of the University of Muenster. Currently, eighteen in-service teachers take part in the project. These ITPP teachers are continuously (further-)qualified for teaching primary sciences over the course of several years. The qualification relates mainly to content knowledge and pedagogical content knowledge in the field of science teaching, as well as basic theoretical knowledge, e.g. in current learning theories, and in the supervision of pre-service teachers. Additionally, the ITPP teachers take part twice a year in shared further education seminars; for example, on the topic of student coaching. They also attend workshops on content and pedagogical content-related themes in science instruction. Experienced ITPP teachers also take over the management of workshops and trainings themselves. In addition, the teachers take part along with pre-service teachers in the regular courses of the bachelor and master's program in primary science education of the University of Münster and work together with them there. Furthermore, they supervise the pre-service teachers’ teaching projects within the framework of university classes by preparing together with them short classroom sequences in natural or technical science topics, accompanying them in testing these in their schools, and finally, mutually reflecting on these classroom situations together. Moreover, the ITPP teachers are also employed in the supervision of primary school pre-service science teachers during their academic practice phases.

In this study, our focus is on the initial internship in the context of the pre-service teacher training program at the University of Münster. This internship involves four weeks of service and must be completed by all pre-service teachers (Ministerium für Schule und Weiterbildung, 2009), usually after the first or second semester as part of the education science studies requirement. As an alternative to the regular internship offered in the educational sciences department, pre-service teachers of primary science education have the opportunity to complete an internship as part of the ITPP-Project in primary school science education. In the ITPP intern-placement, pre-service teachers are sent in small groups of two to four people to ITPP partner schools where they are supervised by ITPP teachers.

RESEARCH QUESTION & HYPOTHESIS

In this study, we investigate the effect of the initial internship on the pre-service teachers’ self-rating for self-efficacy beliefs in relation to their own science teaching. The following question was investigated: What is the relationship between the subjectively perceived change in the self-efficacy beliefs of pre-service teachers regarding science teaching and an internship with different supervision formats? Since ITPP pre-service teachers are able to gain more experience in primary science instruction through the special support of trained ITPP teachers, it is assumed that pre-service teachers who are supervised during their internships by ITPP teachers, will estimate their change in self-efficacy beliefs through the internship with respect to science teaching more positively than pre-service teachers who were not supervised by ITPP teachers.

METHOD

Altogether 125 primary school pre-service teachers from the University of Münster took part in the study, all of whom began their studies in October 2012 or in October 2013 under the current study regulations. Of these, 55 pre-service teachers participated in the ITPP internship (ITPP), while 70 pre-service teachers completed a regular internship (non-ITPP). On average, at the time of the questioning, the pre-service teachers were approx. 22 years old (SD = 3.68) and 87% were female.

In the online questionnaire after the internship, the pre-service teachers estimated on a 4-point rating scale (1 = "strongly disagree" - 4 = "strongly agree"), how their self-efficacy beliefs with regard to science teaching had changed through the internship. They indicated, for example, whether they feel more capable of themselves teaching scientific subjects as a result of the internship. This self-constructed scale for assessing the *change in self-efficacy beliefs concerning their own science teaching* contains three items, and has a high internal consistency (Cronbach's α = .90). In addition, the survey asked questions about aspects of the different aspects of mentoring. The pre-service teachers were asked whether they themselves taught lessons in scientific topics during the internship (1 = yes; 0 = no), whether their supervising teacher, for example, had a connection in their own studies to primary science education (1 = yes; 0 = no) and how many other interns were supervised by the same teacher in the same time period.

In addition, prior to the start of the internship some control variables were collected using a standardized questionnaire (based on Kleickmann, 2008). The pre-service teachers indicated on a 5-point rating scale (0 = "strongly disagree" - 5 = "strongly agree") their *interest in physics* (3 items, Cronbach's α = .79), *estimates of their own abilities in physics* (4 items Cronbach's α = .74), their *interest in teaching physics* (3 items, Cronbach's α = .90), as well as their *estimation of their competency in teaching physics* (3 items, Cronbach's α = .80). The reliabilities of the scales were therefore in satisfactory to good range.

For comparison of the two groups (ITPP and non-ITPP pre-service teachers) with respect to the control variables, a multivariate analysis was calculated. The results show that the two internship groups ITPP and non-ITPP prior to the internship – in relation to the above-mentioned control variables (*interest in physics, abilities in physics, interest in teaching physics, competency in teaching physics*) – did not vary from one another (V = 0.061, F (4,106) = 1.73, p = .149, η_p^2 = .061), so that subsequent analysis of covariance could be omitted in our evaluations.

The comparison of the two internship groups with respect to their estimation of self-efficacy beliefs following the internship and for the analyzed supervision conditions, *taught science* and *teacher with regard to primary science education,* was carried out by means of a *t*-test and multiple X^2-tests. For the variable, *number of pre-service teachers per supervisng teacher,* the conditions for the t-test were not met because the variable was not normally distributed. Thus, in order to get reliable results, the Mann–Whitney *U* test for independent samples was used instead of a *t*-test. Finally, a mediation analysis based on Hayes (2013) was calculated with SPSS, with the estimated change of self-efficacy beliefs as the dependent variable (DV), the group (ITPP, non-ITPP) as the independent variable (IV) and the supervision conditions (*taught science, teacher with regard to primary science education* and *number of pre-service teachers per supervising teacher*) as the mediating variables (M). This was tested in three steps: In the first step, the direct relationship between ITPP participation and the estimation of self-efficacy beliefs was tested via regression analysis. In the second step, the direct relationship between ITPP participation and the reported supervision conditions was individually examined. In the third step, the supervision conditions discussed above were then brought in as mediating variables in the regression analysis.

RESULTS

The result of the *t*-test show that ITPP and non-ITPP pre-service teachers, rate the *change in self-efficacy beliefs concerning their own science teaching* significantly different (t (123) = 3.307, p = .001, d = .60). In Figure 1, the mean values for pre-service teachers' self-evaluations are shown divided into their respective groups (ITPP and non-ITPP).

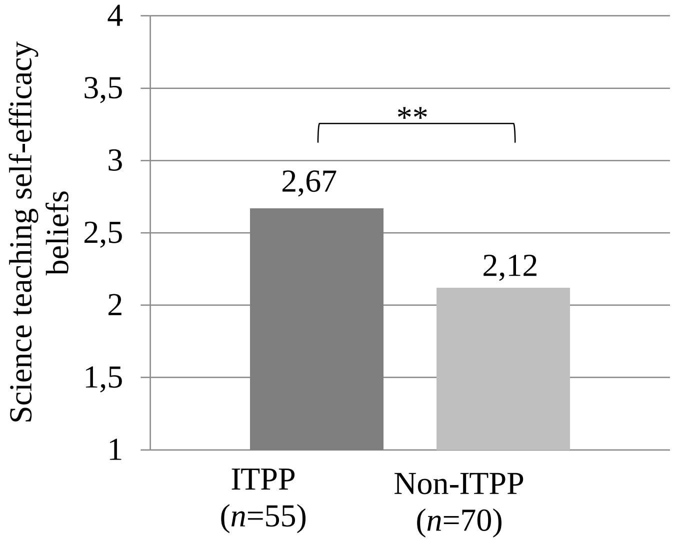

Figure 1. Mean values of pre-service teachers' estimations in the *change in self-efficacy beliefs with respect to their own science teaching* separated by ITPP participation

It can be seen that pre-service teachers who have completed the ITPP internship evaluate the change in their self-efficacy beliefs through the internship significantly more positive than non-ITPP pre-service teachers do.

Additionally, the two internship groups varied significantly from one another in the analyzed supervision conditions: Thus ITPP pre-service teachers have taught lessons self-sufficiently in scientific topics significantly more often (ITPP: 50,9%; non-ITPP: 22,9%) during their internships and were supervised more frequently (ITPP: 87,3%; non-ITPP: 60%) by a teacher with regard to primary science education ($X^2(1) = 10.840$, $p= .001$). Moreover, ITPP pre-service teachers are usually supervised in small groups of up to four pre-service teachers ($Mdn = 2$), while non-ITPP pre-service teachers, in contrast, are usually alone ($Mdn = 0$) during the internship ($U = 3172.50$, $p < .000$).

Subsequent to these results, a mediation analysis was conducted in order to examine the relationship between ITPP participation, estimation of the change in self-efficacy beliefs, and the differences in supervision conditions in greater detail. The results of the mediation analysis are presented in Table 1.

Table 1. Results of the mediation analysis with self-efficacy beliefs in science teaching as DV, ITPP participation as IV, and the supervision conditions: *taught science lessons*, *teacher with regard to primary science education*, and *number of pre-service teacher per supervising teacher* as M variables

	Criteria	Predictor	R^2	β
(1)	Self-efficacy beliefs in science teaching	ITPP participation	.082**	.286**
(2)	Taught science lessons	ITPP participation	.085**	.292***
	Teacher with regard to primary science education	ITPP participation	.094**	.307***
	Number of pre-service teachers per supervising teacher	ITPP participation	.286***	.534***

	Criteria	Predictor	R^2	*β*
(3)	Self-efficacy beliefs in science teaching	ITPP participation	.389***	.191*
		Taught science lessons		.390***
		Teacher with regard to primary science education		.320***
		Number of pre-service teachers per supervising teacher		-.219*

Notes: N = 125; ****p* < .001; ***p* < .01; **p* < .05

Sections 1 and 2 of Table 1 show the relationships between ITPP participation and the pre-service teachers' estimation of self-efficacy beliefs regarding science teaching and between ITPP participation and the various supervision conditions. It can be seen that participation in the ITPP internships has a significant positive influence on self-efficacy beliefs (β = .286). Because a significant, positive correlation also exists between ITPP participation and all three individual supervision conditions (*taught sciences lessons, teacher with regard to primary science education, number of pre-service teachers per teacher*), the conditions of the supervision were then used in a third step as mediators (see section 3 of Table 1). Through the addition of the mediators to the regression model the interrelationship between self-efficacy beliefs and ITPP participation drops considerably (β = .191), but remains nonetheless significant, so there is evidence here of partial mediation through the supervising conditions. The significance of the indirect effects of the three mediators were detected by the Sobel Test (Preacher & Hayes, 2004) and are shown in Table 2 below. All indirect effects are significant at least at the .05 level.

Table 2. Results of the Sobel-Test for the three mediators

Mediator	*z*	*p*
Taught science lessons	2.79	.005
Teacher with regard to primary science education	2.61	.009
Number of pre-service teachers per teacher	2.34	.019

As Table 1 demonstrates, the mediators influence the self-efficacy beliefs of the pre-service teachers in different directions: While practicing one's own teaching in science topics and mentoring support from a teacher with a background in primary science education both have a positive effect on self-efficacy beliefs, the number of pre-service teachers supervised simultaneously by a teacher, had a negative effect. In summary, Table 1 shows that the relationship between the ITPP internship and positive evaluations of self-efficacy beliefs is partly due to the different supervision conditions during the internship.

DISCUSSION AND CONCLUSIONS

Based on the findings, ITPP internships appears to facilitate pre-service teachers at the start of their studies in developing their self-efficacy beliefs regarding science teaching. They support the assumption that the following three conditions may favor the development of self-efficacy beliefs during an internship: 1. the opportunity to gain first-hand experiences in teaching scientific subjects early on, 2. the expertise of supervising teachers in the field of primary science education, and 3. not having too many pre-service teachers per supervising teacher in the internship. It is possible to recognize here partial similarities to other research results, which show that teachers' personal experiences in elementary science teaching (Velthuis et al., 2014) and vicarious experiences through the observation of other teachers (Tschannen-Moran & Woolfolk Hoy, 2007) are important sources for the positive development of self-efficacy beliefs. The relationship between self-efficacy beliefs and mentoring by teachers with a background in primary science education could also be a possible indication that teachers, with their qualifications and the knowledge that they bring to the mentoring situation, have a positive influence on the skill development of pre-service teachers (e.g., Gröschner & Häusler, 2014; Hascher, 2011). The information collected in this study on the supervising teachers is insufficient for a more thorough discussion of this possible impact of teachers in the internship domain. That the factors found so far only partially mediate the relationship between self-efficacy beliefs and participation in an ITPP internship, is an indication that there could be other factors that play a role. For the ITPP internship, the aspect of the supervising teacher seems especially interesting because the pre-service teachers are supervised by teachers whose competences in science teaching were trained through participation in the ITPP Project. However, it remains unclear, which skills the in-service teachers bring with them from this training and to what extent the other teachers who supervise the non-ITPP internships also take part in further-education for primary science teaching and have knowledge and skills in this subject. Therefore, studies are needed that shed a more detailed light on the knowledge and competencies of the supervising teachers: In what aspects do the teachers differ specifically from one another? What differences in qualifications do they bring with them, especially with regard to primary science teaching? Is it possible to recognize relationships between attributes of the teachers and the self-estimated self-efficacy beliefs of pre-service teachers? Through these research questions and in further studies of the influence of the supervising teacher with their knowledge and abilities, the effectiveness of the practice phase and the competence development of pre-service teachers (cf. Gröschner & Häusler, 2014) could be focused on even more closely. In addition to that, the sample of pre-service teachers should to be expanded, as some pre-service teachers at the time of the interview had not yet been completed their internship.

For the future development of the ITPP Project, the results indicate that the number of pre-service teachers who are serving an internship by a mentoring teacher should be reduced. It would be interesting to look at the extent to which the statistical correlations to self-efficacy beliefs persist. It is also desirable to win more in-service teachers for the ITPP Project, thereby enabling more pre-service teachers to receive well-supervised initial teaching experiences in primary science teaching and facilitating through this a tangible increase in their self-efficacy beliefs.

NOTES

1. This book chapter corresponds in parts to the German article: Pawelzik, J., Todorova, M., Leuchter, M. & Möller, K. (under review). „Ich fühle mich sicherer im Unterrichten naturwissenschaftlicher Themen im Sachunterricht“ – Wirkungen eines Praktikums [“I feel sure of myself in teaching scientific topics in primary school science education – Effects of an internship].

REFERENCES

Ashton, P. T. & Webb, R. B. (1986). Teachers’ sense of efficacy, classroom behavior, and student achievement. In P. T. Ashton & R. B. Webb (Eds.), *Teachers’ sense of efficacy and student achievement* (pp. 124-144). New York, London: Longman.

Appleton, K. (2003). How do beginning primary school teachers cope with science? Toward an understanding of science teaching practice. *Research in Science Education, 33*(1), 1-25.

Appleton, K. & Kindt, I. (2002). Beginning elementary teachers’ development as teachers of science. *Journal of Science Teacher Education*, *13*(1), 43-61.

Arnold, K.-H., Gröschner, A. & Hascher, T. (2014) (Eds.), *Schulpraktika in der Lehrerbildung* [Internships in Teacher Education]. Münster: Waxmann.

Bach, A. (2013). *Kompetenzentwicklung im Schulpraktikum. Ausmaß und zeitliche Stabilität von Lerneffekten hochschulischer Praxisphasen* [Competence development in teaching internships. Extent and stability of the learning effects of academic practice phases]. Münster: Waxmann.

Boekhoff, I., Franke, K., Dietrich, F. & Arnold, K.-H. (2008). *Effektivität universitärer Lehrerbildung in konsekutiven Studiengängen (EduLikS) unter besonderer Berücksichtigung schulpraktischer Studien* [The effectiveness of university teacher education in consecutive study programs (EduLikS) with special regard to practical school studies]. Hildesheim: Centrum für Unterrichts- und Bildungsforschung (CeBU).

Gröschner, A. & Häusler, J. (2014). Inwiefern sagen berufsbezogene Erfahrungen und individuelle Einstellungen von Mentorinnen und Mentoren die Lernbegleitung von Lehramtsstudierenden im Praktikum voraus? [To what extent do job-related experiences and the individual attitudes of mentors predict the learning guidance of pre-service teachers in internships?] In K.-H Arnold, A. Gröschner & T. Hascher (Eds.), *Schulpraktika in der Lehrerbildung* (pp. 316-333). Münster: Waxmann.

Gröschner, A., Schmitt, C. & Seidel, T. (2013). Veränderungen subjektiver Kompetenzeinschätzungen von Lehramtsstudierenden im Praxissemester [Changes in subjective competency assessments of student teachers during the practice semester]. *Zeitschrift für Pädagogische Psychologie*, *27*(1-2), 77-86.

Hascher, T. (2012). Lernfeld Praktikum – Evidenzbasierte Entwicklungen in der Lehrer/innenbildung [Internships as learning arenas – evidence-based developments in teacher education]. *Zeitschrift für Bildungsforschung*, *2*(2), 109-129.

Hascher, T. (2011). Forschung zur Wirksamkeit der Lehrerbildung [Research on the effectiveness of teacher education]. In E. Terhart, H. Bennewitz & M. Rothland (Eds.), *Handbuch der Forschung zum Lehrerberuf* (pp. 418-440). Münster: Waxmann.

Hascher, T. (2006). Veränderungen im Praktikum – Veränderungen durch das Praktikum: Eine empirische Untersuchung zur Wirkung von schulpraktischen Studien in der Lehrerbildung [Changes in the teaching internship – changing through internships: an empirical study of the effects of practical studies in teacher education]. In C. Allemann-Ghiona & E. Terhart (Eds.), Kompetenzen und Kompetenzentwicklung von Lehrerinnen und Lehrern: Ausbildung und Beruf. *Zeitschrift für Pädagogik*, 51. Beiheft, 130-148.

Hascher, T. & Moser, P. (2001) Betreute Praktika – Anforderungen an Praktikumslehrerinnen und -lehrer [Supervised internships – the demands on internship teachers]. *Beiträge zur Lehrerbildung, Zeitschrift zu Theorie und Praxis der Aus- und Weiterbildung von Lehrerinnen und Lehrern*, *19*(2), 217-231.

Hayes, A. (2013). *Introduction to mediation, moderation, and conditional process analysis. A regression-based approach.* New York: Guilford Press.

Karstens, C. (2009). *Handlungsmotivation und Unterrichtsqualität – Erfassung affektiv motivationaler Prädiktoren des Unterrichtshandelns von Lehrkräften* [Activity motivation and lesson quality – the measurement of affective and motivational predictors]. Dissertation. Christian-Albrechts-Universität Kiel.

Kleickmann, T. (2008). *Zusammenhänge fachspezifischer Vorstellungen von Grundschullehrkräften zum Lehren und Lernen mit Fortschritten von Schülerinnen und Schülern im konzeptuellen naturwissenschaftlichen Verständnis* [The relationship of elementary teachers' subject-specific beliefs about teaching and learning to the progress of pupils in conceptual understanding in science]. Inaugural-Dissertation. Universität Münster.

Kreis, A. & Staub, F. (2011). Fachspezifisches Unterrichtscoaching im Praktikum. Eine quasi-experimentelle Interventionsstudie [Subject-specific lesson coaching in internships. A semi-experimental intervention study]. *Zeitschrift für Erziehungswissenschaft*, *14*(4), 61–83.

Lamote, C. & Engels, N. (2010). The development of student teachers' professional identity. *European Journal of Teacher Education*, *33*(1), 3-18.

Landwehr, B. (2002). *Die Distanz von Lehrkräften und Studierenden des Sachunterrichts zur Physik. Eine qualitativ-empirische Studie zu den Ursachen* [The 'distance' of in-service and pre-service teachers of natural science to physics. A qualitative-empirical study of the causes]. Berlin: Logos-Verlag.

Ministerium für Schule und Weiterbildung [Ministry of Schools and Further Education] (2009). Gesetz über die Ausbildung für Lehrämter an öffentlichen Schulen (Lehrerausbildungsgesetz – LABG). Bildungsportal des Landes Nordrhein-Westfalen [Act regulating higher education for teaching positions in public schools (Teacher Training Education Act – LABG). Education portal of the state of North-Rhine Westphalia]: Retrieved from https://www.schulministerium.nrw.de/docs/Recht/LAusbildung/LABG/LABGNeu.pdf

Möller, K. (2012). Fachdidaktische Professionalisierung an der Universität und in Schulen – ein Modell für die Kooperation von Universität und Schulen im Rahmen schulpraktischer Studien. [Professionalizing pedagogical content-knowledge at universities and in schools – a model for cooperation between the university and schools in the context of school-practice studies]. *Beiträge zur Lehrerbildung. Zeitschrift zu Theorie und Praxis der Aus- und Weiterbildung von Lehrerinnen und Lehrern*, *30*(2), 209-224.

Möller, K. (2004). Naturwissenschaftliches Lernen in der Grundschule – Welche Kompetenzen brauchen Grundschullehrkräfte? [Natural science learning in elementary school – which competencies do primary school teachers need?] In H. Merkens (Ed.), *Lehrerbildung: IGLU und die Folgen (*pp. 65-84). Opladen: Leske & Budrich.

Mulholland, J. & Wallace, J. (2000). Beginning primary science teaching: entryways to different worlds. *Research in Science Education*, *30*(2), 155-171.

Preacher, K. J., & Hayes, A. F. (2004). SPSS and SAS procedures for estimating indirect effects in simple mediation models. *Behavior Research Methods, Instruments, & Computers*, *36*, 717-731.

Rots, I., Aelterman, A., Vlerick, P & Vermeulen, K. (2007).Teacher education, graduates' teaching commitment and entrance into the teaching profession. *Teaching and Teacher Education*, *23*, 543-556.

Schubarth, W., Gottmann, C. & Krohn, M. (2014). Wahrgenommene Kompetenzentwicklung im Praxissemester und dessen berufsorientierende Wirkung: Ergebnisse der Pro-Pax-Studie [Perceived competency development through practice semesters and their career-orienting effect]. In K.-H. Arnold, A. Gröschner & T. Hascher (Eds.), *Schulpraktika in der Lehrerbildung* (pp. 201-219). Münster: Waxmann.

Staub, F., Waldis, M., Futter, K. & Schatzmann, S. (2014). Unterrichtsbesprechungen als Lerngelegenheiten im Praktikum [Classroom discussions as learning opportunities in teaching internships]. In K.-H. Arnold, A. Gröschner & T. Hascher (Eds.), *Schulpraktika in der Lehrerbildung* (pp. 335-358). Münster: Waxmann.

Tosun, T. (2000). The beliefs of preservice elementary teachers toward science and science teaching. *School Science and Mathematics*, *100*(7), 374-379.

Tschannen-Moran, M. & Woolfolk Hoy, A. (2007). The differential antecedents of self-efficacy beliefs of novice and experienced teachers. *Teaching and Teacher Education*, *23*, 944-956.

Velthuis, C., Fisser, P. & Pieters, J. (2014). Teacher training and pre-service primary teachers' self-efficacy for science teaching. *Journal of Science Teacher Education*, *25*(4), 445-464.

PRE-SERVICE BIOLOGY TEACHERS' COMPETENCE TO USE BASIC PRINCIPLES OF INQUIRY IN THE DESIGN OF LABORATORY TASKS

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Abstract: This contribution is focused on research if pre-service teachers are able to implement inquiry principles into the biology labwork. The research was held during didactic seminars focused on training of didactic methods in relation to school experiments and biological observation. Students (n = 37) were asked to redesign two "classical" laboratory tasks originally developed for the use at the regional level of the Biology Olympiad so that they would change them into an inquiry scheme and to prepare a new design with brief instructions for teaching or conducting of labwork. Although pre-service teachers are introduced to inquiry in several didactic disciplines and inquiry is employed in some scientific disciplines in the teacher preparation, only limited skills based on inquiry were found among pre-service biology teachers in the designing process of laboratory tasks. It was found that students mostly mistake inquiry-based approach for standard ("cookbook") biology lab (simple observation, labwork, performing of simple experiments etc.).

Keywords: inquiry, biology lab, teacher preparation

INTRODUCTION

A lot of studies indicate a clearly positive trend favouring inquiry-based instructional practices (Minner, Levy & Century, 2010). This educational approach has been implemented in successive steps into biology education in the Czech Republic since 2009. Many activities for in-service teachers are organised in order to support the use of inquiry principles as a standard part of biology teaching and learning. Inquiry becomes a standard part of the pre-service teacher preparation in the Czech Republic as well. The data show increasing knowledge about basic principles of inquiry on theoretical level and their application in the school classes (Petr et al., 2015) and inquiry is favoured educational method now.

Most of inquiry activities in education are based on implementation of simple experiments, school labwork or observations. There are many resources of lab tasks but they are not always based on inquiry. Some competition tasks used e. g. in biological competitions have a higher "inquiry potential" because they are based on communication of biological knowledge, stimulate creative or logical thinking and support laboratory competencies and skills. Therefore the use and modification of competition tasks, originally developed for example for the Biology Olympiad, into inquiry-based biology education is discussed (Stuchlikova, Petr & Papacek, 2013, Petr, Stuchlikova & Papacek, 2014).

In the teacher preparation some competition tasks can be used as helpful material for development of teacher's competencies connected with the use of laboratory or experimental tasks in inquiry education.

Next questions were put in the research:

1) Which topic of experiments or observation do the prospective teachers prefer?

2) Which kind of approach to labwork do they prefer?

3) Are the prospective teachers able to apply inquiry in a biology lab?

4) Are they able to transform more or less traditional tasks developed for biology competition into the inquiry model of education?

5) Which aspects of inquiry approach are perceived by students as the most important?

METHOD

Pre-service biology teachers (n=37), were introduced to the principles of inquiry-based biology education and inquiry biology lab before the start of the course of seminars. Each one of them prepared, presented and conducted a simple laboratory task in the seminars. The presented tasks were assessed and discussed in seminars. Besides that, the students were asked to redesign two “standard” laboratory tasks according to the inquiry scheme and to prepare brief instructions for teaching and conducting labwork with the inquiry approach. These model tasks were originally developed for the regional level of the Biology Olympiad and their difficultness was different.

The first task (Anderova & Sima, 2006, Jirickova & Mayerova, 2004) was rather *simple illustration*. This simple experimental task was based on the cultivation and reaction of yeast to different life conditions. This experiment was attended by microscopic observation of yeast cells. The second one (Korcakova & Blazkova, 2005) was rather a *simple observation* with comparison of two events – morphology of different kinds of cells of two moss species (types of tasks are specified by the classification of Chinn & Malhotra, 2002).

Data was collected using a questionnaire and it was analysed using categorization of tasks and related cognitive processes published by Chinn & Malhotra (2002) at the same time basic hierarchy of inquiry-based teaching practices presented for example by Wenning (2005) was taken into consideration.

RESULTS

First part of the research was focused on the analysis of 37 tasks presented in seminars by pre-service teachers.

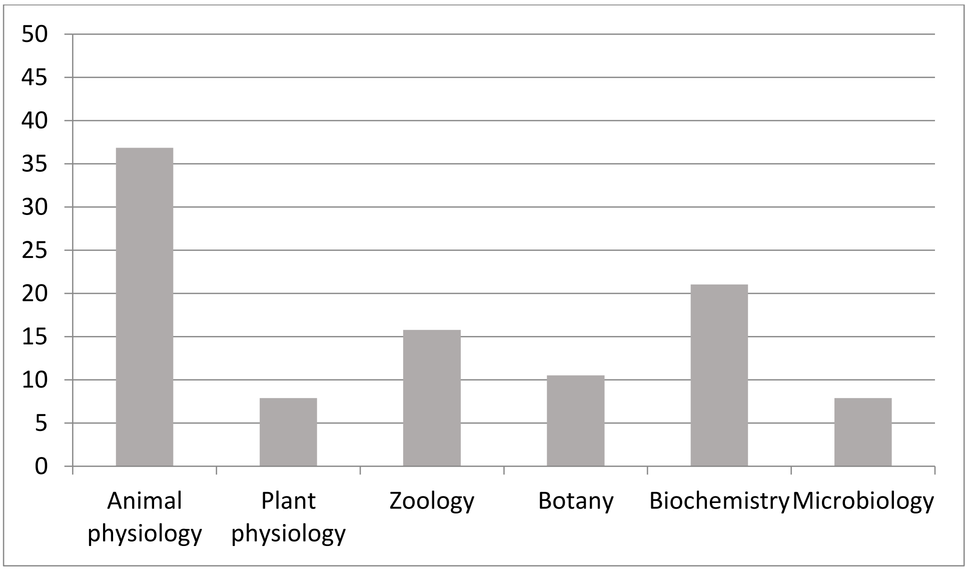

Figure 1. The topic of presented tasks preferred by students (Vertical axis in %)

Presented tasks and experiments can be classified into 6 groups – animal and human physiology, plant physiology, zoology (mostly anatomy and morphology of animals or determination of animal species), botany (analogically), biochemistry (function and proof of biologically active agents, osmosis etc.) and microbiology (for example yeast). The tasks focused on physiology of animals (alternatively physiology of human) and biochemistry were preferred - 58 % of cases together. (Figure 1.)

Pre-service teachers were asked to assess presented tasks or experiments and to determine if they are inquiry or not. Presented tasks focused on plant physiology were considered as a task with largest "inquiry potential". (Figure 2.)

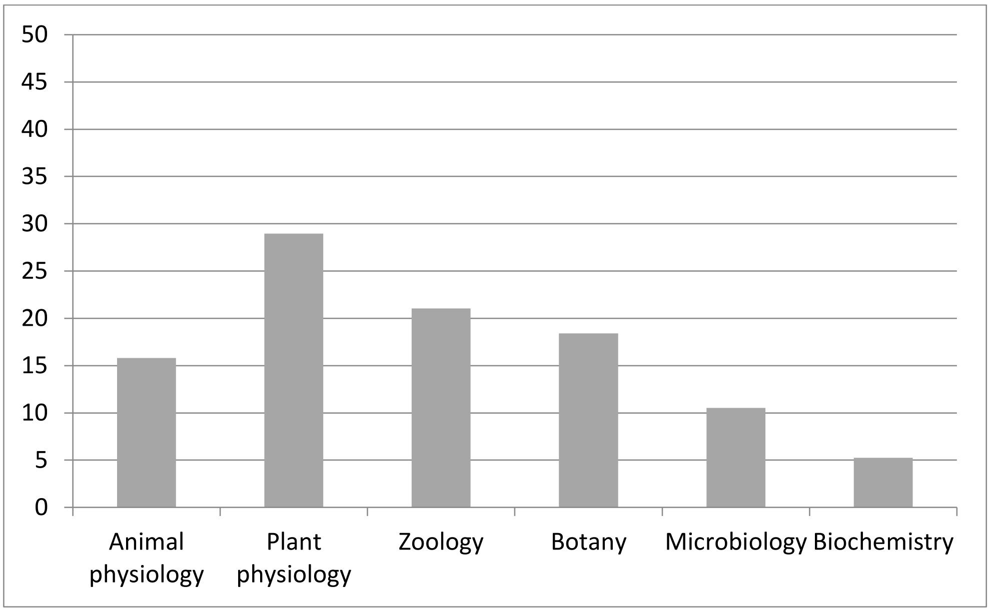

Figure 2. Which presented tasks were "inquiry" in students' opinion? (Vertical axis in %)

From the point of view of didactic application of the tasks, pre-service teachers preferred mainly clear and illustrative tasks (46 % of respondents), interesting and effective tasks (30 %) and simple tasks (22 %). All the presented tasks above were perceived as inquiry-based when they were experimental (38 %) or when they included research questions (21 %). (Figure 3.).

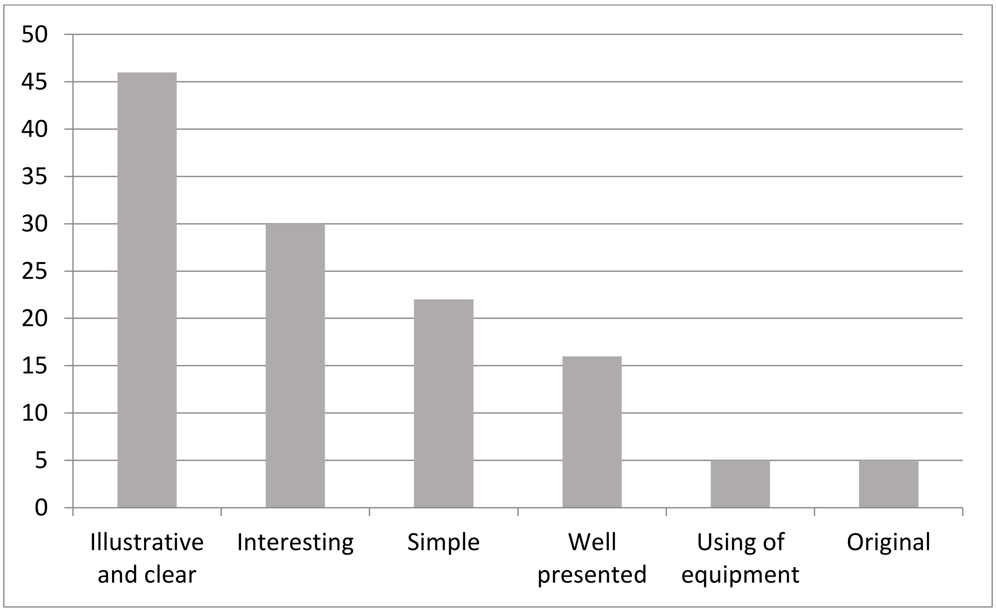

Figure 3. Which presented tasks were preferred by students? (Vertical axis in %)

Second part of the research was focused on the way of redesigning of two simple tasks in seminars by pre-service teachers.

Pre-service teachers had written instructions for two tasks with accessory worksheets at disposal.

TASK 1

Yeast - rather experimental task with microscopic observation of yeast cells.

Students had at disposal:

1) Brief characteristic of yeast.

2) Detailed working procedure.

3) Table for the recording of observations results.

4) Some additional questions.

TASK 2

Moss (*Mnium* sp., *Sphagnum* sp.) - Observational task with comparison of observed events.

Students had at disposal:

1) Brief working procedure

2) Space for sketches of cells of both species.

3) Additional questions focused on water management of the *Sphagnum*.

TASK 1 (yeast) was considered by prospective teachers as more suitable for inquiry education (Figure 4.). About 38 % of respondents found both tasks as usable in inquiry. The second task (moss) was considered as suitable only in 11 % cases.

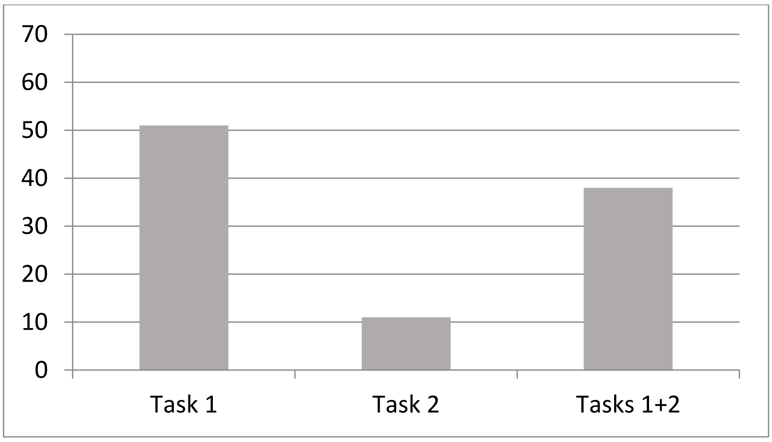

Figure 4. Preference of the tasks for inquiry teaching. (Vertical axis in %)

During redesigning of both tasks prospective teachers formulated new questions, checked experimental design, teaching manual etc. in accordance with inquiry teaching and learning procedures. Some inquiry attributes and steps were used by pre-service teachers. They preferred primarily the formulation of research questions (68 %), searching of experimental design with pupils (51 %) and the formulation of hypothesis (19 %) but not all common steps of inquiry were used. When the pre-service teachers prepared instructions for labwork based on redesigned tasks, about only 30 % of them proposed majority of characteristic attributes of inquiry including complete sequence starting from the formulation of students' own hypothesis up to the final discussion of results and the formulation of new research questions (Fig. 5).

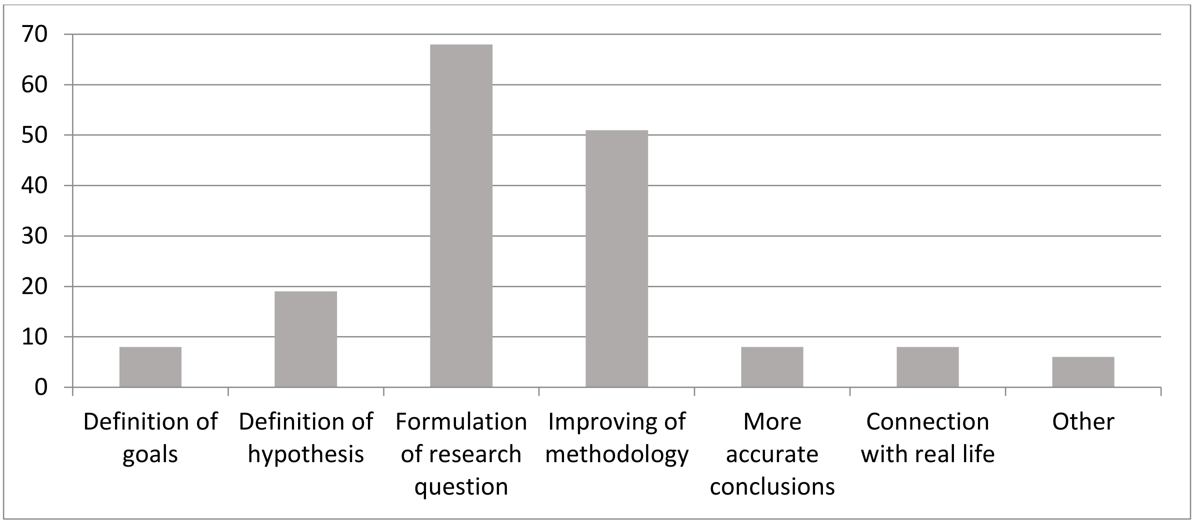

Figure 5. Preferred aspects in the redesigning of the tasks. (Vertical axis in %)

DISCUSSION AND CONCLUSIONS

Physiological and biochemistry tasks were preferred by the pre-service teachers in the seminars. Usually it is due to the dynamic character of these disciplines and therefore a larger expected “inquiry potential” which means more possibilities for the formulation of hypotheses, asking research questions and looking for a design of experiments and potentially for the creation of possibilities for evaluation and explanation of the gathered data.

Only some aspects of the inquiry-based approach are perceived by pre-service teachers as important although the inquiry is characterized by a complex of all components (e. g. sensu Barrow, 2006). The way of students' thinking about redesigning of model tasks into the inquiry approach corresponds with the data gathered in the first part of the research in which prospective teachers marked only some of the presented tasks as inquiry. Prospective teachers preferred mainly the formulation of research question and designing of own methodology of experimental tasks as typical for inquiry lab. Relatively not much of them considered the definition of hypothesis as an important part of inquiry. Other important attributes of inquiry approach in education such as for example discussion and presentation of the gathered data, feedback towards new hypothesis and research question, sharing ideas or critical thinking were mentioned only in few cases (item “other” in the Figure 5.).

It was found that pre-service teachers are (partially) able to redesign selected competition tasks into inquiry. But they mostly mistake the inquiry-based approach for standard (“cookbook”) biology lab (simple observation, labwork, performing of simple experiments etc.). It corresponds with the data published by Petr et al. (2015) which show that about 45 % of in-service teachers mistake (or partially mistake) the above mentioned kinds of educational attitudes as well.

Although this research worked with a not very large group of respondents and it represented more or less a case study, results can help to implement the inquiry principles into the teacher preparation. A good understanding of inquiry principles is a precondition for the improvement of labwork and it represents a challenge for the next work with Czech pre-service and in-service teachers.

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REFERENCES

Anděrová, R. & Šíma, P. (2006). *The Biology Olympiad 2006 – 2007. 41st year. School level of category C. Instruction for competition tasks.* Prague: Institute for children and youth of the Ministry of Education, Youth and Sports. (in Czech)

Barrow, L., H. (2006). A Brief History of Inquiry: From Dewey to Standards. *Journal of Science Teacher Education 17*(3), 265–278.

Chinn, C., A. & Malhotra, B., A. (2002). Epistemiologically Authentic Inquiry in Schools: A Theoretical Framework for Evaluating Inquiry Tasks. *Science Education 86*(2), 175-218.

Jiřička, M. & Mayerová, M. (2004). *The Biology Olympiad 2003 - 2004. 38th year. County level of category C, D.* Prague: Institute for children and youth of the Ministry of Education, Youth and Sports. (in Czech)

Korčáková, H. & Blažková, J. (2005). *The Biology Olympiad 2004 - 2005. 39th year. Regional level of category C.* Prague: Institute for children and youth of the Ministry of Education, Youth and Sports. (in Czech)

Minner, D., D., Levy, A., J. & Century, J. (2010). Inquiry-Based Science Instruction – What Is It and Does It Matter? Results from a Research Synthesis Years 1984 to 2002. *Journal of Research in Science Teaching, 47*(4), 474–496.

Petr, J., Ditrich, T., Závodská, R. & Papáček, M. (2015). Inquiry based biology education in the Czech Republic: A reflection of fiveyears dissemination. In K. Maaß, G. Törner, D. Wernisch, E. Schäfer & K. Reitz-Koncebovski (Eds.), *Educating the Educators: International approaches to scaling-up professional development in maths and science education* (pp. 119–124). Münster, Germany: WTM – Verlag für wissenschaftliche Texte und Medien.

Petr, J., Stuchlíková, I. & Papáček, M. (2014). Biology Olympiad as a model for inquiry approaches, In C. P. Constantinou, N. Papadouris & A. Hadjigeorgiou (Eds.), *E-Book Proceedings of the ESERA 2013 Conference: Science Education Research For Evidence-based Teaching and Coherence in Learning. Part 10* (co-ed. J. Dillon, A. Redfors), (pp. 50–56). Nicosia, Cyprus: European Science Education Research Association.

Stuchlíková, I., Petr, J. & Papáček, M. (2013). Inquiry-based teaching and future teachers' attitudes toward it. In: M. H. Hoveid & P. Gray (Eds.), *Inquiry in Science Education and Science Teacher Education. Questions related to the teaching and learning through inquiry based approaches in science education* (pp. 167–186). Trondheim, Norway: Akademika Publishing.

Wenning, C., J. (2005). Levels of inquiry: Hierarchies of pedagogical practices and inquiry processes. *Journal of Physics Teacher Education Online, 2*(3), 1–12.

USING CORES FOR CAPTURING PEDAGOGICAL CONTENT KNOWLEDGE OF REDOX REACTIONS

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Abstract: This paper aimed to investigate the pedagogical content knowledge (PCK) for teaching redox reactions (RR) among pre-service chemistry teachers. The central purpose was research the pre-service teachers' purposes and goals for teaching redox reactions; their knowledge of curriculum components in the teaching of RR; the knowledge of their students; how they observe students' understanding; and how the pre-service teachers prepare and organize their classes. Data were collected in two different Brazilian Public Universities, with fourteen pre-service chemistry teachers. Content Representation (CoRe) was selected as instrument to capture the PCK. The investigated chemistry teachers answered the CoRe individually during a Methodology course. First, the answers were analyzed individually, and then the central concepts that were closely linked to each other were regrouped resulted in what was called Consensual CoRe. Data were analyzed by the PCK components proposed by the model from Magnusson, Krajick and Borko (1999). Although the answers to CoRe were general, without details, it was possible to gain insight into pre-services teachers' PCK and to observe some aspects of a beginning teacher's PCK. This study elucidated that the investigated pre-service teachers have an insufficient PCK of redox reactions, probably as function of their lack of teaching experience.

Keywords: content representation (CoRe), pedagogical content knowledge (PCK), redox reaction.

INTRODUCTION

The concept of Pedagogical Content Knowledge (PCK) was initially proposed by Shulman (1986), who defines PCK as "that special amalgam of content and pedagogy that is uniquely the province of teachers, their own special form of professional understanding" (Shulman, p.8, 1987). Once Shulman used the expression Pedagogical Content Knowledge (PCK) with the intention of representing the specific professional knowledge of teachers, this expression began to mean something that previously did not have a name (Fernandez, 2014). From that moment, this concept emerged in the literature as an essential knowledge base (Kind, 2009; Fernandez, 2014, 2015; Fernandez & Goes, 2014; Mamlok-Naaman et al., 2013). Although aspects of Shulman's general views are widely accepted, many models of PCK have been proposed. Among these models, Grossman (1990) proposed the first model that characterized PCK, and it is one of the most commonly used. Magnusson, Krajcik e Borko (1999), proposed one model that is one of the predominantly used in science education (Figure 1). This model is based on the model of Grossman and conceptualize PCK for science teaching as consisting of five components: i) orientation to teaching science; ii) knowledge of science curricula; iii) knowledge of assessment; iv) knowledge of students; and v) knowledge of instructional strategies. Orientation to teaching science refers to teachers' knowledge and beliefs about the purposes and goals for teaching science. These orientations are generally organized according to the emphasis in the instruction of a teacher. Each orientation is defined and differentiated according to the objectives for the teaching of science and the typical characteristics of education that should be conducted by the teacher.

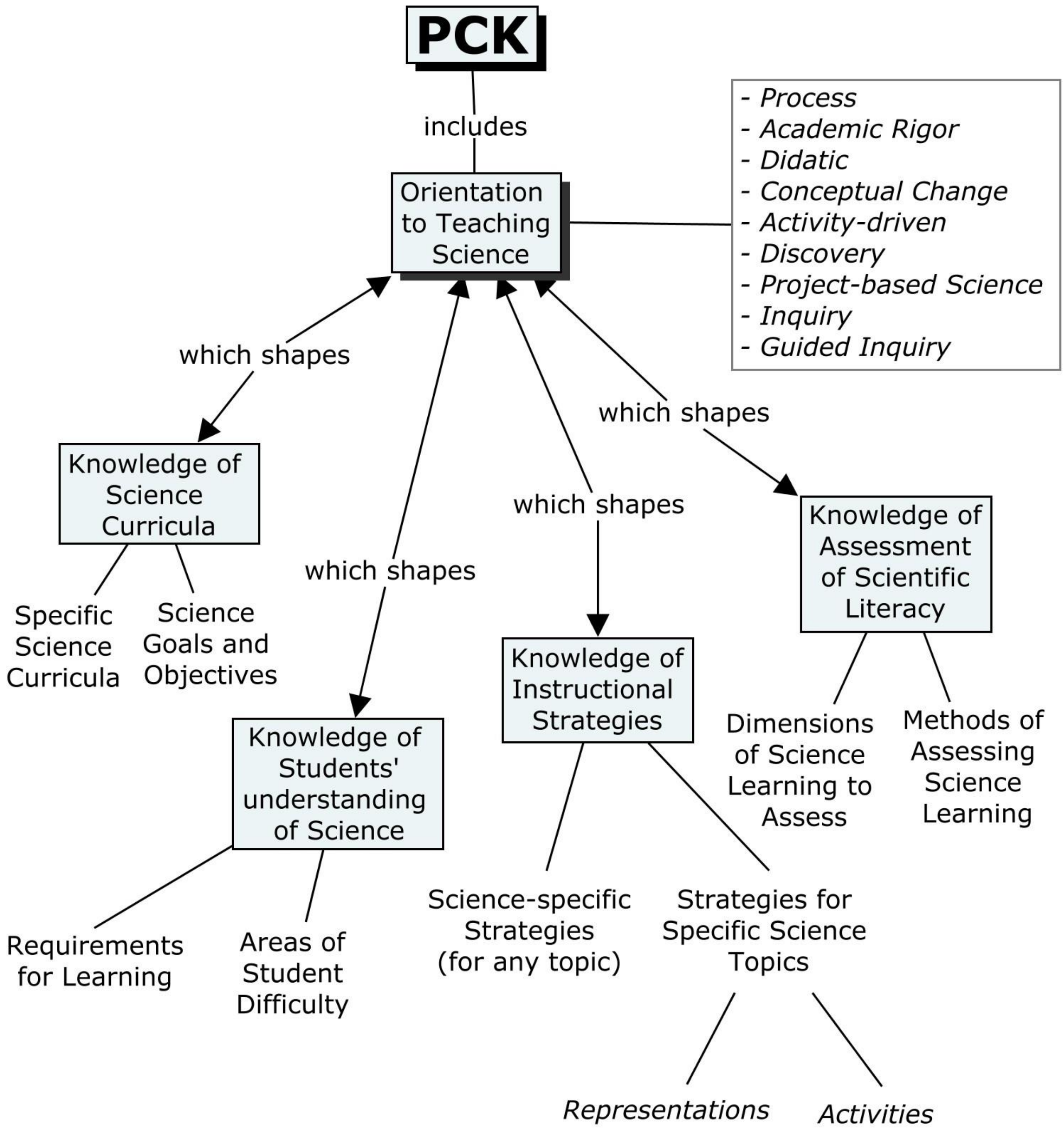

Figure 1. Components of PCK for science teaching (Magnusson, Krajick & Borko, 1999).

Recently, PCK studies have been increasingly developed, especially in science education (Girotto Jr. & Fernandez, 2013; Goes et al., 2013; Montenegro & Fernandez, 2015; Padilla & Van Driel, 2011; Pereira & Fernandez, 2013). Even though there are many researches about PCK, studies reveal that the access to PCK is complex and multiple methodologies are used with the intention to document teachers' PCK (Fernandez & Goes, 2014). Among the tools to capture PCK, Loughran, Mulhall and Berry (2004) proposed a methodological strategy called Content Representation (CoRe), as represented in figure 2. CoRe is a tool that focuses on the understanding of teacher at the points that represent the specific contents, for example, strategies and methodologies. CoRe was designed to get teachers think about their knowledge about how to teach a particular content. CoRe including "the key content ideas, known alternative conceptions, insightful ways of testing for understanding, known areas of confusion, and ways of framing ideas to support student learning" (Loughran, Mulhall & Berry, 2008, p. 1305). It consists of eight questions about the teaching a set of key ideas associated with a specific content and may be carried out in groups or individually. CoRe has been highlighted in the literature and it have been used successfully in pre-service science teacher education to help novice teachers understand what PCK might involve (Fernandez & Goes, 2014; Freire & Fernandez, 2014; Garritz et al., 2007).

IMPORTANT SCIENCE IDEAS/CONCEPTS			
	Big idea 1	Big idea 2	etc
1. What you intend the students to learn about this idea?			
2. Why it is important for the students to know this?			
3. What else you might know about this idea (that you do not intend students to know yet)?			
4. Difficulties/limitations connected with teaching this idea.			
5. Knowledge about students' thinking which influences your teaching of this idea.			
6. Other factors that influence your teaching of this idea.			
7. Teaching procedures (and particular reasons for using these to engage with this idea).			
8. Specific ways of ascertaining students' understanding or confusion around this idea (include likely range of responses).			

Figure 2. Content Representation - CoRe (Loughran, Mulhall, & Berry, 2004).

Redox Reactions: The Subject Matter

Redox reactions (RR) are perhaps the most important of all chemical processes (Soudani et al., 2000). They explain an amazing variety of chemical reactions: the vital biochemical processes such as photosynthesis and metabolism, energy-producing reactions, the corrosion of metals, the production of fertilizers or production of electrochemical cells, among others (Österlund, Berg & Ekborg, 2010). Despite the importance of RR, they are perceived to be one of the most difficult topics, both to learn and to teach (De Jong & Treagust, 2002). Many teachers of high school leave this content to the end of the school year, because of their own difficulties (Freire & Fernandez, 2014; Sanjuan et al., 2009). Among the difficulties faced in the teaching and learning of redox reactions stand out: reduction; electric current; electric conductivity in solutions; representation of redox reactions; reduction potential; dependence between the reduction and oxidation reactions; the transfer process of electrons; the meaning of the oxidation number; identification of the oxidizing and reducing agents; identification of redox reactions and redox reactions balancing (De Jong & Treagust, 2002; Garnett & Treagust, 1992a; 1992b). Moreover, students can not distinguish reactions on a macroscopic level of the substances and the microscopic level of the particles (Barke, Hazarie & Yitbarek, 2009).

Given the centrality of redox reactions concept, this study aims to investigate pre-service chemistry teachers´ PCK of this content. More specifically, investigate the strategies that pre-service teachers commonly use; teachers´ knowledge about student´s difficulties; and their learning goals relate this content.

METHODOLOGY

To investigate PCK of redox reactions (RR) the current study analyzed the answers to questionnaire CoRe of fourteen final year pre-service chemistry teachers from two public Universities in Brazil. Three participants were from the State of Paraná and eleven were from the State of São Paulo. CoRe was presented to the participants and was discussed to orientate the elaboration of the answers. All CoRes were developed on the topic of RR. To answer the data collection instrument, first, each participant selected at least two big ideas.These big ideas formed the top horizontal row of their Redox Reactions CoRe, and the collated content for each big idea was placed immediately below it in the second row, which asks future teachers to consider why it is important for their students to know these big ideas. The student teachers then worked on trying to fill in the rest of the CoRe using their information sources to identify typical learning difficulties, common misconceptions, teaching and learning strategies and assessment methods. The data analysis was performed in two stages. First, the answers were analyzed individually to know which central concepts pre-service cited and which of them were cited at least twice. Then the central concepts that were closely linked to each other were regrouped. Although there is no consensus in the literature about the exact nature of PCK categories, for this analysis, data were analysed using PCK components of Magnusson and colleagues, showed in figure 1.

RESULTS

Initially, the students cited a huge set of different big ideas, 44 in total. This may be result of an imprecise terminology and complex language use during the learning of redox reactions. Moreover, Loughran and colleagues claim that: “too many big ideas suggest the topic may be being “broken down” into “chunks” of information that appear unconnected.” (Loughran, Berry & Mullhall, 2006, p.17). It can be noticed that CoRes were poorly elaborated, in other words, answers were general and did not provide specific detail on classroom practice. It was found that some of the big ideas were closely attached to each other, for example, batteries and electrolysis; reduction potential and oxidation potential, electron transfer and flow of electrons, among others, which were originally listed as different central ideas. Thus, these concepts have been regrouped and reduced to seven central ideas, namely: electron transfer; oxidation and reduction/Nox; oxidation and reduction potential; half-reactions; electrolysis and battery; energy; and applications.

Figure 3 presents the results from the analyse of CoRe questionnaire from the futures chemistry teachers after regrouping the individual ones, it was called Consensual CoRe of redox reactions.

<table>
<tr><th></th><th colspan="7">Consensual Big Ideas</th></tr>
<tr><th></th><th>electron-transfer</th><th>oxidation and reduction/ NOx</th><th>oxidation-reduction potential</th><th>half-reactions</th><th>electrolysis</th><th>energy</th><th>applications</th></tr>
<tr><td rowspan="4">1</td><td colspan="3">understand why there is a transference of electrons</td><td>represent half-reactions</td><td colspan="2">know that electron transfer generate energy</td><td>understand corrosion and protection</td></tr>
<tr><td colspan="2">understand that is a simultaneous process</td><td colspan="3">understand the oxidation potentials</td><td>recognize spontaneity reactions</td><td>understand breathalyzer</td></tr>
<tr><td colspan="2">understand oxidation numbers</td><td rowspan="2"></td><td rowspan="2"></td><td colspan="3" rowspan="2">understand the phenomena involved in the industry</td></tr>
<tr><td colspan="2">understand gain or loss of electrons</td></tr>
<tr><td rowspan="3">2</td><td colspan="4">to understand redox reactions</td><td colspan="3">to make relation between daily events</td></tr>
<tr><td colspan="3">it is a knowledge base</td><td>to balance chemical reactions</td><td colspan="3">to judge environmental and economic impacts</td></tr>
<tr><td colspan="2">to make relation between daily events</td><td>to calculate the standard oxidation potential and relate to reactions of spontaneity</td><td></td><td></td><td>to bring awareness to the role of chemistry</td><td>to relate oxidation and humidity</td></tr>
<tr><td rowspan="5">3</td><td>metal corrosion</td><td rowspan="5">cyclic voltammetry</td><td>Nernst equation</td><td rowspan="5">disproportionation reaction</td><td rowspan="5">Nernst equation</td><td rowspan="5">electromagnetism</td><td rowspan="5">biochemical process</td></tr>
<tr><td>it is an important concept to understand other phenomena</td><td>spontaneity</td></tr>
<tr><td>promising applications</td><td rowspan="4">Gibbs energy</td></tr>
<tr><td>kinetics of Electron Transfer</td></tr>
<tr><td>Nernst equation</td></tr>
<tr><td rowspan="2">4</td><td colspan="2">abstraction</td><td>previous knowledge</td><td rowspan="2">understand the direction of the electrons</td><td>abstraction</td><td rowspan="2">redox reactions</td></tr>
<tr><td>relationship of macroscopic and microscopic concepts</td><td>calculations of NOx</td><td>oxidation potential not dependent on the number of moles</td><td>balancing chemical reactions</td><td>signals</td></tr>
<tr><td rowspan="3">5</td><td colspan="2">representation model</td><td rowspan="3">relate oxidation potential to energy</td><td rowspan="3">simultaneous process</td><td rowspan="3">abstraction</td><td>balancing chemical reactions</td><td>rusting</td></tr>
<tr><td>oxidation-reduction potential</td><td rowspan="2">oxidation is only relate with gain of oxygen</td><td>limitation to thermal energy</td><td rowspan="2">controversy over alcoholic beverages</td></tr>
<tr><td rowspan="2">previous knowledge</td><td>knowledge about electronics</td></tr>
<tr><td rowspan="3">6</td><td rowspan="3">difficult matter</td><td rowspan="3">previous knowledge</td><td rowspan="3">stoichiometry</td><td>electron transfer</td><td rowspan="3">interest in electronics</td><td>curiosities</td></tr>
<tr><td>energy generation and consumption</td><td>equipments</td><td>analogies</td></tr>
<tr><td>chemicals bonds</td><td>laboratory</td><td>common sense</td></tr>
<tr><td rowspan="5">7</td><td colspan="7">experiences</td></tr>
<tr><td colspan="4">exercises</td><td rowspan="4">field study</td><td>relate with daily events</td><td rowspan="4">discuss</td></tr>
<tr><td colspan="2">use of technology</td><td colspan="2">relate with daily events</td><td>use of technology</td></tr>
<tr><td>relate with daily events</td><td rowspan="2"></td><td rowspan="2"></td><td rowspan="2"></td><td>historical aspects</td></tr>
<tr><td>review concepts of electricity</td><td></td></tr>
<tr><td rowspan="4">8</td><td colspan="6">written test</td><td rowspan="2">workshop</td></tr>
<tr><td colspan="6">exercises</td></tr>
<tr><td rowspan="2">lab report</td><td rowspan="2"></td><td>workshop</td><td rowspan="2"></td><td rowspan="2">lab report</td><td rowspan="2"></td><td rowspan="2">team work</td></tr>
<tr><td>team work</td></tr>
</table>

Figure 3. Consensual CoRe by the fourteen pre-service chemistry teachers.

DISCUSSION

The future teachers only cited the ideas, without explanation or connection. For example, they write *electron transfer* as one big idea, in this case, they could elaborate the answer, and explain what they want to say with electron transfer. The answer could be: oxidation-reduction reactions involve electron transfer. The understanding of the big ideas is important because they are the main concepts of teaching an area of specific content pertaining to the disciplinary knowledge of the teacher, normally used for lesson planning. The big ideas, presented in Figure 3, highlight a number of concepts as being commonly viewed as important to students develop to a significant understanding of the content of redox reaction.

Although CoRes were poorly elaborated, it was still possible to take a view of pre-service chemistry teachers' PCK. Although each one has a different structure in his/her PCK, there are some trends that can be observed. Thus, a generalization for each PCK component is presented.

Orientation toward science teaching

The first and the second question of the CoRe (what you intend the students to learn about this idea and why it is important for students to know this) are a starting point to investigate the purposes and goals for teaching. They are a "beginning point in unpacking science teachers' understanding of what matters in a particular content area and (…) why it is important to be taught." (Loughran, Berry & Mullhall, 2006, p.17). From figure 3, it can be noticed that many cited concepts are common and the most cited one is the concept of electron transfer. The participants expected that students understand that in a redox process, there are elements that loses electron while another gains. Besides that, the pre-service chemistry teachers expected that their students understand the oxidation potentials. It is interesting to notice that the future teachers describes potential in terms of oxidation and not in terms of reduction. This preference may be due to the language in textbooks that normally use both terms without mentioning that oxidation potential is a convention.

As previously mentioned, there are answers that seems too simplistic or which do not consider much more important ideas. For example, mention that it is important to learn half-reactions to balance chemical reactions. Balancing turns out to be a consequence of understanding of the process. The electrochemical potential is independent of the mass and dependent of nature and the physical and chemical properties of each element. Another example, to the big idea application, future teachers cited that the importance of learning this idea is relate oxidation and humidity. This highlights something very simplistic, decontextualized and it shows lack of knowledge of these students in relation to the objectives of teaching the content of redox reaction.

Among the nine orientations to teaching science identified by Magnusson, Krajick and Borko (Figure 1), only two emerged from the CoRe: "Academic Rigor" and "Process". It means that the teaching of chemical content does not necessarily bring the articulation with other areas. The consensual CoRe suggests that pre-service teachers believe that it is essential to understand the use of the key concepts in real situations. In five of the seven big ideas, pre-service teachers said that learning redox reaction is important to make relation between daily events. In four big ideas, the importance is to understand redox reactions. In addition, in three big ideas, the importance is because redox reactions is a knowledge base. Besides that, judge environmental and economic impacts were the justifications for three big ideas for teaching redox reactions.

Knowledge of science curriculum

The third question (what else you might know about this idea (that you don't intend students to know yet)) is related to curriculum component. This row of the CoRe explicit what needs to be included and what needs to be exclude in order for students to begin to develop an understanding of the redox reactions. Knowledge of Science Curriculum corresponds to knowledge that teachers must present about programs and materials that are relevant to the teaching of a particular content of science. Thus, the teachers' curriculum knowledge should include knowledge of the general goals of the curriculum learning, as well as the activities and materials to carry out these goals.

From figure 3, it is observed that there are citations of concepts that appear in a random manner. For example, pre-service teachers cited Nernst equation for two big ideas: electron transfer and electrolysis/battery. Does this concept has the same priority to these two ideas? It seems that it was a cited concept only because it has something relate with redox reactions. Another example is to mention electromagnetism in the big idea energy. Electromagnetism is important in study of energy production but in very different contexts.

It can be seen that pre-service teachers focused mainly on disciplinary content. It is possible to say that the participants have knowledge of the limited number of curriculum components in the teaching of redox reactions. They cited concepts normally seen only in undergraduate courses like Nernst Equation, kinetics of electron transfer, disproportionation reaction, cyclic voltammetry and Gibbs energy. These are concepts more complex that a high school student not necessarily needs to learn.

It is observed that there is almost no relationship between other knowledge of chemistry area or other areas. Also, pre-service teachers have unclear of what influences student learning on redox reactions and what are the previous knowledge required for teaching redox reactions.

Furthermore, pre-service teachers do not have knowledge of what are the contents that influencing the study of redox reactions, i.e., the prior knowledge required for teaching RR. They could have listed the understanding of: reactivity; properties of the elements; chemical bounds, or tendency to turn cation or anion. Anyway, they could have cited several others concepts that is important to the learning of RR. It demonstrates a lack of knowledge of the curriculum and of the teaching context.

Knowledge of students' understanding of science

The fourth and the fifth questions of CoRe (difficulties/limitations connected with teaching this idea and Knowledge about students' thinking which influences your teaching of this idea) are very important to make explicit what teachers should know about the knowledge of their students and how this knowledge influences their teaching. The answers to fourth and fifth questions provide understandings of alternative conceptions and potential difficulties when teaching the topic of redox reactions. There are few concepts listed by pre-service teachers as necessary for learning the topic. The abstraction of the phenomena is the main problem reported by them. In addition, they identify some misconceptions commonly related to redox reaction, such as relationship of macroscopic and microscopic concepts; disregard of the simultaneity of oxidation and reduction processes; the confusion of oxidation with gain of oxygen; and the meaning of the terms oxidizing and reducing agents (Österlund, Berg & Ekborg, 2010).

The pre-service teachers did not report anything about cathode and anode or about the signs of the poles or even about salt bridge. Moreover, they did not point the difference between oxidation numbers, ionization numbers and the numbers around an element symbol. These are important concepts related to the redox reactions content, which are targets as concepts of great difficulties and of possible misconceptions.

Knowledge of instructional strategies

The seventh question (teaching procedures (and particular reasons for using these to engage with this idea)) reveals teachers' knowledge of specific strategies to teaching. The participants cited a few varieties of teaching strategies with a basic description of what was involved. Furthermore, they did not explain the particular reasons for using that. For example, pre-service teachers cited exercises as strategies, but only said exercise is too broad. They could have been more specific and gave examples of exercises.

It is observed that the preference is for experiments, exercises, and the relationship with technology. For all big ideas, experiences were cited as strategies. Moreover, activities that relate the content of redox reactions with daily events were cited in four big ideas. They did not cited the use of videos or animations, for example. It is believed that the lack of experience leads to a poor repertoire of instructional strategies.

Knowledge of assessment in science

The eighth question (specific ways of ascertaining students' understanding or confusion around this idea) is designed to investigate how teachers monitor students' understanding. According to Figure 3, it can be observed that the knowledge of the methods of assessments of these pre-service teachers is limited. Besides this, they did not explain the specific reasons for the use of these ways of ascertaining student understanding. It is interesting to note that while in the previous question, pre-service teachers proposed experiences as a teaching strategy for all big ideas, in the eight question, for the assessment, laboratory report only appears for two big ideas.

They could have proposed practical assessment, i.e., hands on activities, for instance, carry out some electrolysis and then produce half equations or a discussion of relevant examples, like rusting or aluminum production. It is important that pre-service teachers know that the assessment should be a continuous process because it reveals especially those students who need more assistance.

CONCLUSIONS

This study aimed to document the PCK for redox reactions of pre-service chemistry teachers who studied in two different Universities in Brazil. PCK has been well accepted as a useful construct by the academic community. The questionnaire CoRe was used to portray PCK of future chemistry teachers. The answers to the CoRe were analyzed within the PCK components suggested by Magnusson, Krajick and Borko (1999).

It is remarkable the diversity of central concepts (44) mentioned by pre-service teachers. The individual pre-service teachers' CoRes were used to determine the seven central concepts to teaching redox reaction and produce a consensual CoRe about redox reactions. In general, answers to questionnaire CoRe were poor elaborated, without many details. From analysis of the Consensual CoRe, it was possible to observe some aspects of pre-services teachers' PCK about redox reactions.

All teachers highlight its connection to everyday life and considered the redox reaction very important. From the data analyze is observed that pre-service teachers have a poor knowledge of science curriculum and they do not recognize students' difficulties about redox reactions. In relation to the teaching and learning difficulties on the subject, teachers cited only few students' misconceptions. They need to deepen their understanding of the misconceptions and difficulties of students on the redox reactions. In addition, they need to improve many points related to their PCK about this content. They need to improve their knowledge of instructional strategies and how they observe students' understanding. These points will probably be better developed along the teaching experience. Moreover, they need to pay more attention to the assessment because it shows that the process is going well or not.

It is important to note that PCK actually refers to the integration between its different components. The answers to the CoRe instrument are revealed of the lack of connection between the content redox reactions and its teaching for the investigated teachers. From the analysis, it can be seen that the investigated teachers have an insufficient PCK on redox reactions. This highlight the importance of rethinking the initial training courses, and try to provide grants for undergraduates develop their PCK. The use of the questionnaire CoRe can be a good start to promote teacher reflection on a particular content. From the answers of pre-service teachers, it would be possible to conduct interviews and try to get more information for those questions that have not been clarified in the CoRe. At the same time, make them think about their answers and consequently on their practices.

ACKNOWLEDGEMENTS

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REFERENCES

Barke, H.D., Hazari, A. & Yitbarek, S. (2009). *Misconceptions in Chemistry*. Berlim: Srpinger.

De Jong, O. & Treagust, D. (2002). The teaching and learning of electrochemistry, in J. K. Gilbert, O. De Jong, R. Justi, D. F. Treagust and J. H. van Driel, eds., *Chemical Education: towards research-based practice* (317-337), Dordrecht: Kluwer.

Fernandez, C. (2014). Knowledge base for teaching and Pedagogical Content Knowledge (PCK): some useful models and implications for teachers training. *Problems of Education in the Twenty First Century*, 60(1), 79-100.

Fernandez, C.; (2015). Revisitando a base de conhecimentos e o Conhecimento Pedagógico do Conteúdo (PCK) de professores de ciências. Ensaio: Pesquisa em Educação em Ciências (Online), 17, 500-528.

Fernandez, C. & Goes, L.F. (2014). Conhecimento pedagógico do conteúdo: estado da arte no ensino de ciências e matemática. Em: Garritz, A.; Rosales, S.F.D; Lorenzo, M.G. (Eds.). *Conocimiento Didáctico del Contenido. Una perspectiva Iberoamericana*. (65-99). Saarbrücken, Alemania: Editorial Académica Española.

Freire, L.I.F. & Fernandez, C. (2014). Professores novatos de química e o desenvolvimento do PCK de oxidorredução: influências da formação inicial. *Educación Química*, 25, 312-324.

Garritz, A.; Porro, S.; Rembado, F.M. & Trinidad, R. (2007). Conocimiento pedagógico de profesores latinoamericanos sobre la naturaleza corpuscular de la materia. *Revista de educación em ciências*, 8(2), (79-84).

Garnett, P.J. & Treagust, D.F. (1992a). Conceptual difficulties experienced by senior high school students of electrochemistry: electric circuits and oxidation-reduction equations. *Journal of Research in Science Teaching*. 29(2), (121-142).

Garnett, P.J. & Treagust, D.F. (1992b). Conceptual difficulties experienced by senior high school students of electrochemistry: electrochemical (galvanic) and electrolytic cells. *Journal of Research in Science Teaching*. 29(10), (1079-1099).

Girotto, Jr., G. & Fernandez, C (2013). Following early career Chemistry teachers: the development of Pedagogical Content Knowledge from pre-service to a professional teacher. *Problems of Education in the Twenty First Century*, 55, 57-73.

Goes, L.F.; Leal, S.H.; Corio, P. & Fernandez, C. (2013). Aspectos do Conhecimento Pedagógico do Conteúdo de Química Verde em professores universitários de Química. Educación Química, 24(1), 113-123.

Grossman, P.L. (1990). The making of a teacher: teacher and teacher education. New York: Teachers College Press.

Kind, V. (2009). Pedagogical content knowledge in science education: perspectives and potential for progress, *Studies in Science Education*, 45(2), 169-204.

Loughran, J., Mulhall, P. & Berry, A. (2004). In search of pedagogical knowledge in science: Developing ways of articulating and documenting professional practice, *Journal of Research in Science Teaching*, 41(4), 370-391.

Loughran, J., Berry, A., & Mullhall, P. (2006). Understanding and developing science teachers' pedagogical content knowledge. Rotterdam, The Netherlands: Sense Publishers.

Loughran, J., Mulhall, P., & Berry, A. (2008). Exploring pedagogical content knowledge in science teacher education. *International Journal of Science Education*, 30(10), 1301–1320.

Magnusson, S., Krajckik, J. & Borko, H. (1999). Nature, sources and development of pedagogical content knowledge for science teaching. In: Gess-Newsome, J., Lederman, N.G (Eds.), *Examining pedagogical content knowledge* (95-132). New York: Kluwer Academic Publishers.

Mamlok-Naaman, R.; Rauch, F.; Markic, S. & Fernandez, C. (2013). How to keep myself being a professional chemistry teacher. In: Ingo Eilks; Avi Hofstein. (Org.). *A Studybook: A Practical Guide and Textbook for Student Teachers, Teacher Trainees and Teachers* (269-297). Rotterdam, The Netherlands: Sense Publishers.

Montenegro, V.L.S. & Fernandez, C. (2015). Conhecimento Pedagógico do Conteúdo numa intervenção formativa com professores de Química. Ensaio: *Pesquisa em Educação em Ciências*, 17(1), 251-275.

Österlund, L.L., Berg, A. & Ekborg, M. (2010). Redox models in chemistry textbooks for the upper secondary school: friend or foe? *Chemical Education Research and Practice.* 11, 182-192.

Padilla, K. & Van Driel, J. (2011) The relationships between PCK components: the case of quantum chemistry professors. *Chemistry Education Research and Practice*, 12(3), 367-378.

Pereira, P.G.E.M. & Fernandez, C. (2013). Indícios do modelo integrativo no desenvolvimento do PCK em licenciandos em Química durante o estágio supervisionado. *Revista de Educacion de las Ciencias*, 14(2), 74-78.

Sanjuan, M.E.C.; Dos Santos, C.V.; Maia, J. de O.; Da Silva, A.F.A. & Wartha, E. J. (2009) Maresia: Uma Proposta para o Ensino de Eletroquímica. *Química Nova na Escola*, 31(3).

Shulman, L. (1986). Those who understand: knowledge growth in teaching. *Educational Researcher*, 15(1), 4-14.

Shulman, L. (1987). Knowledge and teaching: Foundations of the New Reform. *Harvard Educational Review*, 57(1), 1-22.

Soudani, M., Sivade, A., Cros, D. & Médimagh, M. S. (2010). Transferring knowledge from the classroom to the real world: redox concepts. *School Science Review*, 82 (298), 65-72.

LANGUAGE AND SCIENCE EXPERIENCE NARRATIVES OF PRE-SERVICE PRIMARY TEACHERS LEARNING TO TEACH SCIENCE IN MULTILINGUAL CONTEXTS

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Abstract: The command of at least three languages is considered one of the most important basic educational competences in Europe. In response to this demand new teaching approaches have been promoted, such as *Content and Language Integrated Learning* (CLIL), which could be included in the broad umbrella of bilingual education. A CLIL approach to science education implies the teaching of both science and foreign language in the same classroom and by the same teacher mostly. This study characterizes and compares student teachers' science and language experience narratives as a way to capture the experiences that might have shaped their beliefs about science and languages. A content analysis is performed on student teachers' written narratives reflecting on the relevant experiences related to science and languages along their life span. Two main dimensions have been developed for the analysis: (a) the experience context (family, school, community and future), and (b) the experience nature (educational, psychological, social and utilitarian) creating 16 different experience fields. The results indicate that the science narratives are mostly rooted in school contexts, oriented towards its teaching in school only, and associated to learning difficulties. This is in strong contrasts with the language experience narratives which appear to be anchored in a wide variety of contexts, for purposes that go beyond school, and associated to progressive and positive learning trajectories. The question for science teacher education lies in how to help student teachers make connections between both life trajectories. New science teacher education experiences can be created where different languages are tools for science learning and where science becomes a context for learning languages.

Keywords: Science experience narratives, Science teacher education, CLIL, Multilingualism

INTRODUCTION

The specificity of European multilingual contexts in education

The educational demands that a global society places on most European education systems are high. One of these demands is related to fact that our society and schools are multilingual contexts and that language diversity is a cultural heritage in need of conservation. The command of at least three languages is considered one of the most important basic competences that every European citizen should acquire through compulsory education (European Commission, 2007). However the repertoire of language use in Europe can be seen as divided in two types of multilingualism (Guasch & Nussbaum, 2007): a first order multilingualism constituted by the big European languages which are strongly valued and worth learning, and the second order multilingualism constituted by the minority languages present as a consequence of immigration which can be tolerated but have a lower status.

The multilingual context experienced in Catalonia adds a third factor making multilingual education more difficult. In fact, Catalonia is an autonomous region of Spain considering itself a nation without a state. The Catalan social and cultural identity is built around the core element of its particular language Catalan which has been suppressed throughout the history of the country in several occasions and particularly during the time of General Franco's dictatorship. The revival of the Catalan language only began after Franco's death, in 1975, at the birth of Spanish democracy. Since then, language policies promulgated by the Catalan government have had an important role in ensuring that Catalan is now commonly used in many aspects of daily life including education. The region has officially two languages: Catalan and Spanish although the school system has adopted a compulsory immersion model in Catalan as a tool for social cohesion. The Spanish central government is at present legislating against the use of Catalan in schools. Any attempt to introduce new languages in the education system might be considered a potential danger for Catalan extinction and might add extra tension in the Catalan education system.

A content and language integrated learning approach (CLIL) to primary science education

In response to this demand, European educational institutions at all levels are developing new teaching approaches which could be included in the broad umbrella of bilingual education. Cummins, one of the fathers of multilingualism in education, defined bilingual education as the "use of two or more languages of instruction at some point in a student's school career" (Cummins, 2008, p.xii). One of the bilingual education approaches recently promoted in Europe has been the "Content and Language Integrated Learning" (CLIL). This approach advocates the need to design learning environments in which both specific content and a specific foreign language can be taught and learned together: "The acronym CLIL is used as a generic term to describe all types of provision in which a second language (a foreign, regional or minority language and/or another official state language) is used to teach certain subjects in the curriculum other than languages lessons themselves" (Eurydice, 2006, p. 8). A CLIL approach to science education implies the teaching of both science content and foreign language in the same classroom and by the same teacher. Multilingual science education contexts are very varied with multiple models and structures existing in different European education systems. In this paper we want to present the case of Catalonia, Spain which has developed a particular model on multilingualism in education that strongly affects primary science education.

The challenges of CLIL primary science teacher education

When developing CLIL approaches in primary science classrooms in Catalonia, teachers need to manage the learning of science and the learning of three languages at the same time: Spanish, Catalan and English, the last one being a foreign language. Primary teachers usually feel unconfident about the mastery of a foreign language such as English and about the way to teach it. In contrast English specialist teachers teaching in CLIL science classrooms feel unconfident about teaching science and especially inquiry based science. The consequence of this is that the profile of primary teachers who teach science in Catalan schools is changing and that the quality of the science taught is seriously at stake. Efforts have been made into the investigation of primary science teacher education in multilingual contexts (Ramos & Espinet, 2013). The present research work focuses on student teachers' experiences as important factors influencing beliefs and practices on teaching science and languages in primary CLIL science classrooms.

METHODOLOGY

This study is framed under a narrative approach to research in education (Cortazzi, 1993) and teacher education (Goodson, 2003). We take the concept of *Experience Narrative* from Rivera (2011) as a subset of life story. The life story consists of narratives of self that reconstruct the past, connect to the present, and anticipate the future. In her study Rivera focuses on the importance of the language experience narratives in the development of pre-service science teachers' trajectories so that these experiences become visible and ready to be critically scrutinized.

The aim of the study is to characterize and compare student teachers' science and language experience narratives (SN and LN from now on) when learning to teach science as a way to capture early experiences that might shape their beliefs about science and languages. These beliefs are important since they frame student teachers' future practices as CLIL science teachers. More specifically the questions addressed by this study are the following:

a) What kind of language and science experiences are important in the lives of pre-service teachers prior entering CLIL science teacher education courses?
b) How can pre-service teachers' science and language experiences narratives be compared?

Eighteen student teachers wrote one science and one language experience narrative in 2014 when attending two different subjects related to science education. Both subjects were offered in different semesters by the Primary Education Graduate Program at the Autonomous University of Barcelona, Catalonia, Spain. Student teachers were encouraged first to write the language experience narrative at the beginning of the second semester 2013-14 within the subject *Teaching and Learning about the environment in primary education. S*econdly they were encouraged to write a science experience narrative and the beginning of the first semester 2014-15 during the subject *Didactics of Science.* The guidelines shown in Table 1 were used to orient students' free style writing of both the language and the science experience narratives.

A content analysis was performed on each student teacher's written narrative reflecting on the relevant experiences related to science and languages along their life span. Two main dimensions were inductively developed during the analysis: (a) the *Experience Context*, and (b) the *Experience Nature*. The experience context dimension characterizes the type of social organization where the student teachers' experiences are enacted such as the family, the school, the community and finally the future orientation. The experience nature dimension refers to the value of student teachers' experience as being educational, psychological, social and utilitarian. This last dimension has been inspired by the work of CRECIM (2012) on motivation to pursue scientific careers.

The crossing of these two dimensions has created *16 fields of experience* which have been relevant for the characterization and comparison of pre-service primary teachers' language and science experience narratives. Each statement from the narratives was associated to one field of experience in order to obtain two types of quantitative data: percentages of narratives expressing statements of a particular field experience, and absolute number of statements from all narratives associated to a particular field of experience (Table 3). In addition a descriptive analysis of the narratives as texts was performed taking into account the structure, the temporal referents, and the language used in the writing of the narratives (Table 2a and Table 2b).

Table 1: Questions guiding pre-service science teachers' writing of science and languages experience narratives

Languages Experience Narrative (LN)	Science Experience Narrative (SN)
Your relationship with different languages:	***Your relationship with Science outside school:***
What languages are you familiar with? How competent in writing, speaking, listening and reading you feel you are? What languages would you have liked to learn? Why? What type of experiences have you undergone through your life where language was an important component?	How much do you like science? Why? How competent in writing, speaking, thinking and doing science do you feel you are? What family models in science do you have? What issues or topics would you have liked to learn? Why? What type of experiences have you undergone through your life in which science was an important component? (Science museums, science centers, science summer camps, TV programs, scientific literature etc.)
Your experience with the teaching and learning of languages:	***Your experience with the teaching and learning of science:***
What type of language teaching and learning experiences have you undergone through your life? How do you evaluate them? What languages have been important for you in your educational and working experiences? What have your feelings been in relation to the teaching and learning of different languages? What are your expectations in life and in the university in relation to the use and learning of languages?	What type of experiences in teaching and learning sciences have you undergone through your life? How do you evaluate them? What sciences, if any, have been important for you in your educational and working experiences? What have your feeling been in relation to the teaching and learning of science? What are your expectations in life and in the university in relation to the learning of science?

RESULTS

The descriptive analysis shown in Table 2a and Table 2b provide a characterization of experience narratives as written texts. The narrative structure selected by the majority of student teachers is sequential, although the thematic structure is quite relevant in the case of language experience narratives. Students are very much aware of the life experiences related to different languages and in most cases these experiences are different. Whereas Catalan is the language used to write the language experience narrative, students switch to English when it comes to the writing of the science experience narrative. This could probably be explained as a result of maturity and security in using English. Finally students reconstruct their language and science experiences using a complete temporal referent which includes past, present and future.

Table 2a: Descriptive analysis of language experience narratives (N=18)

Number of students: 18			**Language used**	Catalan	15
				English	2
				Spanish	1
Narrative Structure	Sequential	9	**Temporal referent**	Past-Present-Future	13
	Thematic/languages	6		Past-Present	2
	None of the above	3		Past	3

Table 2b: Descriptive analysis of science experience narratives (N=18)

Number of students: 18		**Language used**	Catalan	4
			English	14
			Spanish	0
Narrative Structure	Sequential 10	**Temporal referent**	Past-Present-Future	15
	Thematic 0		Past-Present	1
	None of the above 8		Past	2

Table 3 shows the quantitative analysis of pre-service primary teachers' narratives according to the 16 fields of experience. Pre service primary teachers' experience narratives in science and language have commonalities and differences in relation to the experience fields they have reconstructed. The experience narratives as a whole have privileged the school and community experience contexts over the family and future experience contexts. In addition, the nature of the mentioned experiences has been mostly educational, and to a lesser degree social and psychological.

Table 3. Experience fields of pre-service teachers' language experience narratives (LN) and science experience narratives (SN).

Experience Nature / Experience Context	EDUCATIONAL SN	EDUCATIONAL LN	PSYCOLOGICAL SN	PSYCOLOGICAL LN	SOCIAL SN	SOCIAL LN	UTILITARIAN SN	UTILITARIAN LN	TOTAL
FAMILY	16% 5		5% 1	5% 1	89% 26	94% 46		16% 5	84
SCHOOL	100% 141	100% 131	61% 19	83% 46	28% 5	78% 27	16% 4	16% 3	376
COMMUNITY	22% 4	22% 10	16% 4	72% 21	22% 7	83% 30	22% 5	55% 22	103
FUTURE	72% 22	61% 24	44% 9	5% 1			11% 2	16% 4	62
TOTAL	172	165	33	69	38	103	11	34	625

*In each cell there is a percentage of experience narratives indicating the experience field (N=18). The number in each cell indicates the total amount of experiences mentioned in the 18 experience narratives in relation to the experience field. The shadowed cells indicate content discrepancy between science and language narratives.

Interesting differences can be found when comparing the experience fields of SN and LN. Whereas the nature of the scientific experiences reconstructed in the SN had mostly an educational nature, the language experiences reconstructed in the LN showed a richer nature by introducing experiences of an educational, psychological and social nature. In fact, student teachers appreciated the experiences provided in the school and the community contexts related to the learning of different languages in multilingual contexts, the participation within a diversity of community activities in which different languages were involved, or the possibility of traveling. This is coherent with the utilitarian nature of experiences mentioned in the LN, where student teachers indicated the social, personal and professional utility of commanding different languages.

Both narratives, SN and LN, reconstructed experiences associated to family and future oriented contexts. Whereas the nature of experiences located within family contexts were of a social nature, those oriented into the future mostly had an educational nature. In fact student teachers seemed to be very much aware of the important role played by the family in relation to creating a positive environment through the use of different languages. This role, as expressed within the SN, was reduced to accessing scientific media, books, and talks. In relation to the future oriented contexts reflected in the narratives, SN identified experiences related to increasing the motivation towards science and being a better science teacher, whereas the LN focused on the acquisition of degrees and the increasing of language fluidity in use.

CONCLUSIONS

This preliminary analysis supports the idea that pre-service teachers construe their past experiences with science and languages in a very different way. The science experiences of the student teachers in this study appear to be located mostly in school contexts, oriented towards its teaching in school only, and associated to learning difficulties. This is in strong contrasts with language experiences which appear to be anchored in a wide variety of contexts, for purposes that go beyond school, and associated to progressive and positive learning trajectories. These results point at the issue of the isolation of science within social life of our students. The question for science teacher education lies in how to help student teachers make connections between both life trajectories so that they become resources for professional development.

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REFERENCES

Cortazzi, M. (1993) *Narrative analysis*. London: The Falmer Press

CRECIM (2012). Career decisions: which factors influence career choices and how do people make career decisions?. *Observatory Methodology*. Public Report of the InGenious - ECB project. Retrieved from http://www.ingenious-science.eu/c/document_library/get_file?uuid=e234e812-67eb-4fc4-b05f-1b51e074614e&groupId=10136.

Eurydice. (2006). *Content and Language Integrated Learning (CLIL) at School in Europe. Brussels:Eurodyce European Unit.* Retrieved from http://ec.europa.eu/languages/documents/studies/clil-at-school-in-europe_en.pdf

European Commission (2007). *High Level Group on Multilingualism. Final Report.* Belgium: Official Publications of the European Community.

Goodson, I.F. (2003). Hacia un desarrollo de las historias personales y profesionales de los docentes. *Revista mejicana de investigación educativa*, 8(19), 733-758.

Guasch, O. & Nussbaum, L. (Eds.) (2007). *Aproximacions a la competència multilingüe.* Bellaterra: Universitat Autònoma de Barcelona.

Ramos, S.L. & Espinet, M. (2013) Expanding the agency in multilingual science teacher education classrooms. In N. Mansour & R. Wegerif (Eds.) *Science Education for Diversity*, Dordrecht, NL: Springer, 251-275.

Rivera, M. (2011). Language experience narratives and the role of autobiographical reasoning in becoming an urban science teacher, *Cultural Studies of Science Education*, 6, 413-434.

INTEGRATED SCIENCE EDUCATION OF PRIMARY AND MIDDLE SCHOOL TEACHERS AT UNIVERSITY

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Abstract: Teachers in Germany are often trained in only one of the disciplines biology, chemistry and physics although numerous curricula provide an integrated subject science. There are different reasons to establish such an integrated subject not only in school curricula but in pre-service teacher education at universities: perspective of the students/learners, perspective of the (future) teachers, and perspective of educational policy. The pilot project NWT (science and technology) which aims to improve pre-service teacher education at the University of Regensburg by doing integrated science started in 2009. The external evaluation in 2012 was very successful and the ongoing process is to establish NWT and thus implement a teacher education reform in collaboration with the ministry.

NWT students are similarly trained in all three natural sciences. The courses are designed and run collaboratively from both a scientific perspective as well as a subject didactics perspective. Interdisciplinary topics and applied contents are essential. In addition the future teachers consider students' experience in everyday-life and their everyday concepts. Therefore empirical studies are conducted and classes come to the laboratories at university to carry out experiments and to be individually promoted by NWT students.

From the very beginning research focussed on the assessment of the program and the characterization of the NWT students and their development, for example their personal technical focus and need of support, their self-concept skills concerning biology, chemistry and physics, and their self-efficacy in teaching biology, chemistry and physics. Data was collected several times during the education and longitudinal analyses show that the NWT-studies seem to have positive effects on the above mentioned issues. The characteristics of the NWT concept as well as quantitative findings from the research accompanying the pilot project in pre-service teacher education will be presented in this paper.

Keywords:

Science Education, Initial Teacher Education (Pre-service), Self-Concept Skills, Self-Efficacy

BACKGROUND, RATIONALE AND PURPOSE

Introduction

Imagine three situations of everyday-life:

- in the motor of your car you burn up fuel
- you see an object with your eyes
- your lunch makes your hair and nails grow.

Would you analyse and explain these situations with biology, chemistry, physics or technology? For most phenomena in everyday-life several disciplines are needed. In Germany teachers are often trained in only one of the disciplines although numerous curricula provide an integrated subject science. There are different reasons to establish such an integrated subject not only in school curricula but in pre-service teacher education at universities.

Reasons for an Integrated Science Education

a) Perspective of the students/learners

Children do not notice their environment divided into biology, chemistry, physics and technology but as a whole. The holistic view facilitates the perception of connections, joined-up thinking, and the discussion on problems in everyday-life, environment, and society (Rehm et al., 2008). Besides, an integrated concept has positive effects on the attitudes of young people towards science education and reduces gender differences on this issue (Bennett et al., 2007).

b) Perspective of the (future) teachers

Considered internationally science education in school is often organized as one integrated subject (for reasons see a)) instead of single disciplines (e. g. Canada, Australia, USA, Great Britain, The Netherlands, Switzerland, Norway…), (Möller, 2007; Rehm et al., 2008). In Germany lots of teachers (primary and middle school) face the problem that they are only trained in one of the disciplines (mostly biology) and have to teach physics and chemistry as well.

c) Perspective of educational policy

Scientific literacy and development are essential for our society. Therefore more and especially better trained teachers for science and technology are needed in most countries. These teachers should foster the interest and the competencies of their students in an optimal way. Policy makers encourage schools to strengthen their profile in the natural sciences.

Characteristics of the NWT Concept

The pilot project NWT (science and technology) started in 2009 and aims to improve pre-service teacher education. A target agreement was made between the Ministry of Science, Research and the Arts and the University of Regensburg to reform teacher education. Therefore, primary and middle school teachers are similarly trained in all three natural sciences and in integrated science. The NWT program should result in both more and better trained teachers than before.

The improvement of pre-service teacher education should be reached by the following:

- The courses are designed and run collaboratively from both a scientific perspective as well as a subject didactics perspective. School and instruction are focused from the very beginning while elaborating different science contents.
- NWT students have to be active in all courses, for example by conducting experiments and reflecting them, and by cooperative learning.
- Interdisciplinary topics and applied contents are essential. There is a large variety of courses to be chosen by the students, for example “weather, climate, environment” or “transformation, transport and storage of energy in nature and technology” or “bionics”.
- NWT students are exclusively educated in small groups. This guarantees that everyone is deeply involved.
- As an essential part of their education the future teachers consider students’ experience in everyday-life and their everyday concepts. Therefore empirical studies are conducted and classes come to the laboratories at university to carry out experiments and to be individually promoted by the NWT students.

The NWT-studies are divided into two phases. In the first phase, the students attend basic and advanced training courses in biology, chemistry, and physics (scientific perspective as well as a subject didactics perspective). At once all students take an additional course in general science didactics. The second phase is characterized by integrated science courses. This is the moment where school classes of more than 130 collaborating teachers come to the laboratories at university so that the future teachers can experience the students' everyday concepts and carry out experiments they have planned on their own or elaborated together with the children. As mentioned above, there is also a large variety of interdisciplinary courses to be chosen by the NWT students. Overall the NWT-studies (during the pilot project as a subsidiary subject at university) comprise 32 credit points for primary school teachers and 41 credit points for middle school teachers.

EMPIRICAL STUDY

Research Questions, Method and Procedure

Each new teacher education program has to be assessed. In the following, I restrict to some of the research questions:

- Is the pilot project NWT successful in recruiting more students for the natural sciences than the traditional teacher education (single disciplines) in former times?
- What is the personal technical focus and need of support of the NWT students when entering university?
- Can the self-concept skills and the self-efficacy in teaching biology, chemistry, and physics of the NWT students be developed in a positive way?
- Would they study NWT as a main subject if they had the chance to?

Beside others, the research accompanying the pilot project comprises a questionnaire. In addition, statistics of the University of Regensburg have been analyzed. The questionnaire was proved in a pilot study in 2009 with 204 participants. The (sub)scales showed satisfying up to excellent reliabilities.

The questionnaire comprehends:

- personal data
- science and technology (NWT)
  (reasons for choosing the subject, personal need of technical support, importance of different aspects for the own NWT-studies…)
- biology, chemistry, physics, integrated science
  (interest in the school subject, interest in the discipline, self-concept, personal relevance, interest in teaching, self-efficacy…)
- instruction related competencies
  (subject matter, learner, teacher)

As figure 1 shows data was and is collected before the first phase of the NWT-studies (time 1), between the two phases (time 2) and after the second phase (time 3). The development of the NWT students shall thus be tracked over the whole period of pre-service teacher education at university (about four years). Furthermore we plan to continue these studies during the first years in-service of our alumni.

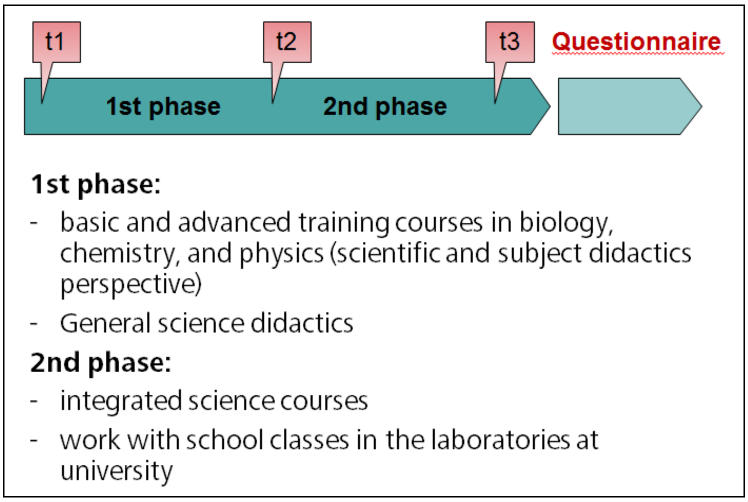

Figure 1. Data collection (t1, t2, t3) during the NWT-studies.

Analyses and Findings

The original planning at university referred to 60 students for the new subject NWT each year. This calculation was based on former statistics (education in single disciplines) where in average 54 persons per year decided to study biology, 7 physics, and 3 chemistry to become a primary or middle school teacher. As a matter of fact there are about 90 - 100 students per year to be educated in integrated science. Thus NWT brings more (future) teachers into the natural sciences. Two thirds of our students want to become a primary school teacher, one third a middle school teacher.

Before the first phase of the NWT education (time 1) the students (N = 507) were asked about their personal technical focus. Figure 2 presents that the great majority (342 students) gave the answer “biology” whereas most support was needed in physics (258 students) and in chemistry (213 students). It is one of the main objectives of the project to train the students similarly in all three natural sciences.

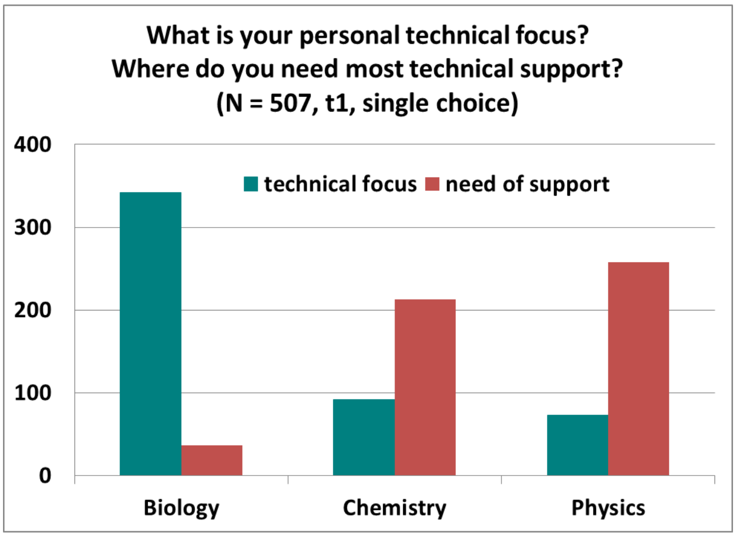

Figure 2. Personal technical focus and need of support of the NWT students when entering university.

Further psychometric data was collected using some modified scales originally developed by Kleickmann (2008). The answering scale reached from 1 (low) to 5 (high).

How do you rate your present skills in biology, chemistry and physics? With four items such as “There is no fundament for me to deal with topics in physics” each self-concept skill was rated by the students (N = 507, time 1). It is high gear concerning biology (M = 3.93, SD = .68), in chemistry (M = 3.04, SD = .87) and physics (M = 2.91, SD = .86) about the theoretical mean (table 1).

How do you rate your competence to teach biological, chemical and physical topics? The self-efficacy in teaching was ascertained each with four items like “I dare to teach in a way that the students are able to understand biological topics” (N = 507, time 1). We have analogical findings as seen for the previous construct: the highest self-efficacy in teaching was rated concerning biology (M = 3.98, SD = .70), followed by chemistry (M = 3.32, SD = .90) and physics (M = 3.18, SD = .86), (table 1).

Table 1. Self-concept skills and self-efficacy in teaching of the NWT students when entering university.

Self-concept skills (N = 507, time 1)	***How do you rate your present skills in biology, chemistry and physics?****(1 = low, 5 = high)*			
	M	SD	Number of items	Cronbachs α
Biology	3,93	.68	4	.83
Chemistry	3.04	.87	4	.87
Physics	2.91	.86	4	.87
Self-efficacy in teaching (N = 507, time 1)	***How do you rate your competence to teach biological, chemical and physical topics?*** *(1 = low, 5 = high)*			
	M	SD	Number of items	Cronbachs α
Biology	3.98	.70	4	.82
Chemistry	3.32	.90	4	.87
Physics	3.18	.86	4	.85

Longitudinal analyses (N = 125) were computed using the General Linear Model (GLM) Procedure of the statistical software SPSS. Figure 3 and figure 4 suggest that the self-concept skills and the self-efficacy in teaching stay on the same high level (figure 3) or increase (figure 4) concerning biology, while there is a considerable increase for chemistry and physics. The self-efficacy in teaching chemistry rose with a big effect size (Cohens d = .842***) from time 1 to time 3, also the self-efficacy in teaching physics (Cohens d = .549***), both figure 4. Similar results are found for the development of the self-concept skills from time 1 to time 3 in chemistry (Cohens d = .871***) and physics (Cohens d = .462***), both figure 3.

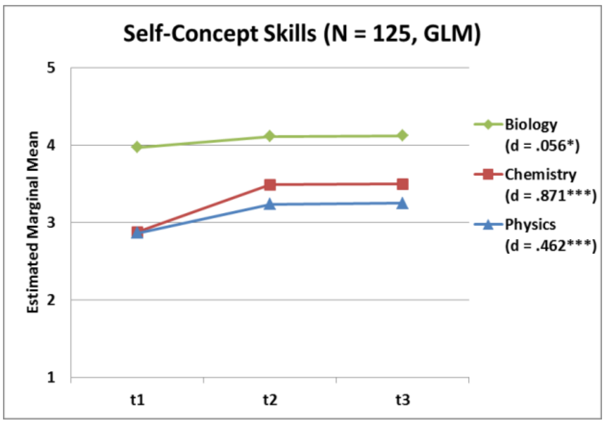

Figure 3. Development of the self-concept skills of the NWT students.

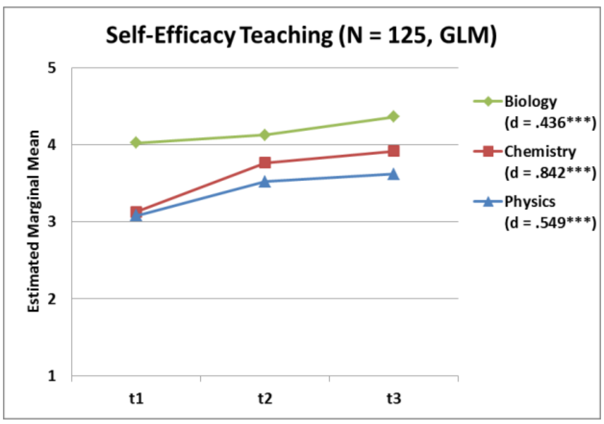

Figure 4. Development of the self-efficacy in teaching of the NWT students.

As long as NWT exists as a pilot project it can only be studied as a subsidiary subject at university. Irrespective of the external evaluation in 2012 (evalag) that recommended to extend NWT as a main subject in the future, our students have been asked from the very beginning whether they would study integrated science as a main subject if they had the chance to. Figure 5 shows that more than 60% said “no” for time 1 while 40% would choose this option. To integrate this result: about 10% of the NWT students are enlisted for biology as a main subject at present, scarcely anybody for physics or chemistry. If one takes a closer look for time 2 and time 3 (figure 5) half of the future teachers would study NWT as main subject.

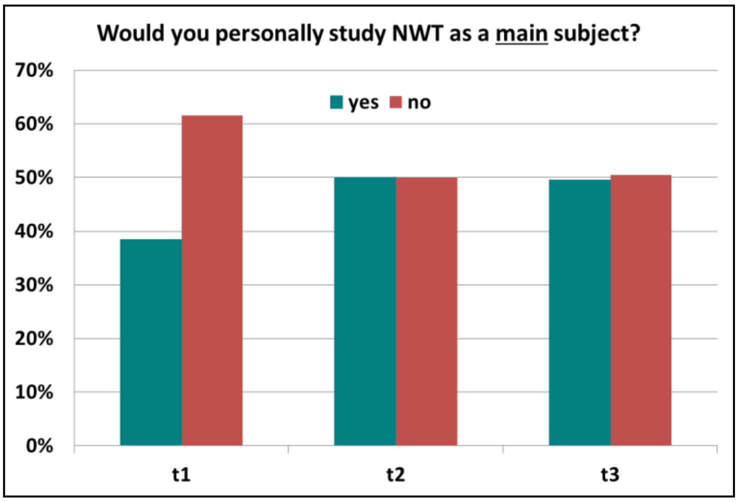

Figure 5. Opinion towards NWT as a main subject.

SUMMARY, CONCLUSIONS AND GENERAL INTEREST

The pilot project NWT is a unique program to improve pre-service teacher education at university by doing integrated science. It brings more teacher students into the natural sciences than the former education in single disciplines. Much more students enlisted for the new subject at university as expected. At the beginning of their NWT-studies most of them need support in physics and chemistry than in biology. This corresponds with the situation of teachers in many primary and middle schools in Germany. Referring to the longitudinal model, NWT seems to develop the self-concept skills of the students and their self-efficacy in teaching quite well, especially in chemistry and physics. Furthermore we plan to continue the research during the first years in-service of our alumni.

The external evaluation (peer review process complying with national and international standards) in 2012 (evalag) was very successful and NWT should thus be established at universities not only as a minor subject, but also as a major subject in the future. Concerning this issue it is a remarkable result that the percentage of those who would study NWT as a main subject has risen to 50% and lies clearly higher than for the single disciplines. NWT doesn’t seem to frighten the students but to encourage them. This corresponds with the findings from the longitudinal model. Although NWT was awarded a prize in 2014 by the Academy of the Bavarian Teacher Association the establishment is still an ongoing process with the ministry and will hopefully contribute to a better long-term situation in the schools.

REFERENCES

Bennett, J., Lubben, F. & Hogarth, S. (2007). Bringing Science to Life: A Synthesis of the Research Evidence on the Effects of Context-Based and STS Approaches to Science Teaching. *Science Education*, 91, p. 347-370.

Evalag (2012). *Modellversuch Naturwissenschaft und Technik (NWT). Didaktikfach für das Lehramt an Grund- und Hauptschulen an der Universität Regensburg. Evaluationsbericht.* Mannheim: evalag.

Kleickmann, T. (2008). *Zusammenhänge fachspezifischer Vorstellungen von Grundschullehrkräften zum Lehren und Lernen mit Fortschritten von Schülerinnen und Schülern im konzeptuellen naturwissenschaftlichen Verständnis*. Münster: Inaugural-Dissertation.

Möller, K. (2007). „Primary Science" – ein internationaler Überblick. In: D. Höttecke (Ed.). *Naturwissenschaftlicher Unterricht im internationalen Vergleich*. Münster: LIT, 27, p. 98-121.

Rehm, M., Bünder, W., Haas, T., Buck, P., Labudde, P. Brovelli, D., Östergaard, E., Rittersbacher, C., Wilhelm, M., Genseberger, R. & Svoboda, G. (2008). Legitimierungen und Fundamente eines integrierten Unterrichtsfachs "Science". *Zeitschrift für Didaktik der Naturwissenschaften*, p. 99-124.

TEACHING ABILITIES OF PROSPECTIVE TEACHERS AT THE BEGINNING OF THE PRACTICAL PHASE OF TEACHER EDUCATION

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Abstract: The focus of the study lies on the development of teaching abilities of prospective teachers during the practical phase of teacher education. German teacher education is segmented into a scholarly phase at university and a practical phase at school, comparable to an induction phase. The main goal of the practical phase is to learn how to teach, which can be divided into planning, conducting and reflecting on lessons. These three domains are particularly important because the quality of instruction is a crucial precondition for students' learning and because reflecting on lessons is a precondition for professional development of teachers. Therefore the study analyses the development of planning, conducting and reflecting on lessons in natural and social sciences during the practical phase of teacher education. Twelve prospective teachers were investigated at the beginning, in the middle and at the end of the practical phase of teacher education. Their written lesson plans, videotaped lessons and transcribed oral reflections on the lessons were analysed. This paper focuses on the abilities the prospective teachers have at the beginning of the practical phase when they have only just left university. The analyses of the first time of measurement reveal differences between the prospective teachers. All prospective teachers have abilities to plan, conduct and reflect on lessons, but for some it is an enormous challenge. Furthermore, at the beginning of the practical phase of teacher education the prospective teachers take aspects regarding the structure and organisation of lessons stronger into account than aspects regarding the individual level of students.

Keywords: teacher education, practical phase, lesson planning, conducting lessons, reflecting on lessons

FOCUS OF THE STUDY

A competent teacher is a key determinant for pupils' achievement (e.g. Hattie, 2009). For this reason the number of studies concerning the professional competence of teachers and their education increased over the last years. Only by knowing about developmental processes teacher educators are able to improve the education (Blomberg, Renkl, Gamoran Sherin, Borko & Seidel, 2013).

German teacher education is segmented into two phases: The scholarly phase with a duration of four to five years is carried out at an institution of higher education, e.g. a university. The practical phase is comparable to an induction phase. It has a duration of one to two years and is conducted in schools and supervised by state-run departments (Viebahn, 2003). The main goal of the practical phase is to learn how to teach, which can be divided into planning, conducting and reflecting on lessons (Niemi, 2011). Learning how to teach is particularly difficult in complex subjects like *Sachunterricht* which combines all natural and social sciences at German primary school level.

The study described here, analyses the development of planning, conducting and reflecting on lessons in the subject *Sachunterricht* during the practical phase of teacher education. To analyse the process of development, it was necessary to create instruments to measure and rate the abilities in all three domains. The project is divided into three sub-projects which address the three domains planning, conducting and reflection separately. This paper focuses on the abilities the prospective teachers have at the beginning of the practical phase when they have only just left university.

THEORETICAL BACKGROUND

The quality of instruction is a precondition for students' learning (e.g. Hattie, 2009). For this reason a lot of research on instructional quality has been carried out as well as different sophisticated theoretical models and catalogues of criteria for high quality teaching (e.g. Brophy, 2000; Helmke, 2009; Slavin, 1994). These criteria should be implemented into lessons as well as into lesson plans to guarantee high quality teaching. The model of Helmke (2009) comprises ten criteria for high quality teaching, e.g. classroom management, clarity and structure, activation of cognitive abilities. Based on these criteria Pietsch (2010) developed and validated a phased model to classify the quality of teaching, see figure 1. An analysis of more than 2000 lessons revealed that criteria on level 1 were implemented in all lessons. In a lot of lessons criteria on level 2 were implemented additionally. In some of these lessons criteria on level 3 were implemented additionally and in some of these lessons criteria on level 4. Each level includes the previous one. It can be assumed that criteria on the structuring and organising level (1 & 2) are easier to implement into a lesson than criteria on the individual level of students (3 & 4).

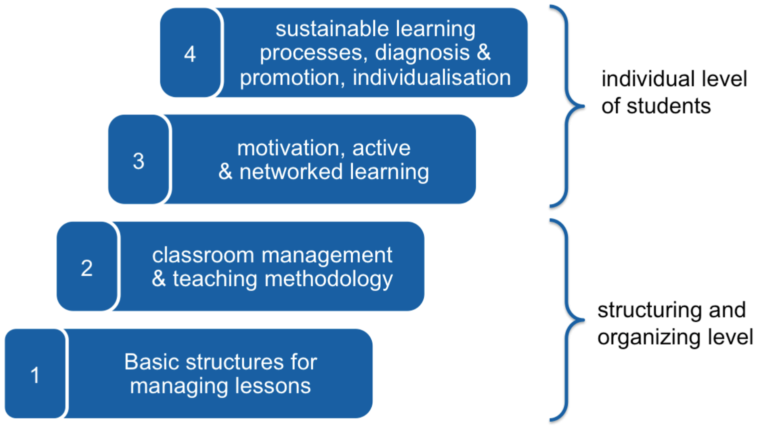

Figure 1. Four phased model to classify the quality of teaching (Pietsch, 2010)

How prospective teachers learn to plan and conduct lessons with regard to criteria for high quality teaching over the time of teacher education is widely uninvestigated (e.g. Niemi, 2011). Some studies show that general teaching abilities as well as abilities to plan lessons increase over the time of practical phases. Not all abilities increase consistently, but some develop faster than others e.g. efficiency of instruction, economic use of time and cognitive activation (Baer et al., 2011; Niemi, 2011; Wideen, Mayer-Smith & Moon, 1998). None of these studies concentrates on the complex subject *Sachunterricht*, but most on general didactical aspects and none of these studies focuses on the practical phase of teacher education. Furthermore most of these studies are based on self-evaluation and there is a need of external rated research.

It is assumed that reflecting on lessons supports the development of planning and teaching abilities: To reflect on lessons is a precondition for professional development of teachers because the interaction between practice and theoretical reflection is the basis of development (Kansanen, 2000; Schön, 1983). Beyond that it is assumed that the ability to reflect on lessons increases through practice (Dewey, 1933).

RESEARCH QUESTIONS & HYPOTHESES

Derived from the theoretical background the goal of the presented study is to answer the question: How do abilities to plan, conduct and reflect on lessons in the subject *Sachunterricht* develop over the time of the practical phase of teacher education? It is expected that the abilities increase over time and that criteria on the structuring and organising level develop earlier than criteria on the individual level of students. With regard to the beginning of the practical phase of teacher education it is expected that the abilities in the three domains are not generally high and that there are differences between specific abilities because some develop earlier than others.

METHODS & DESIGN

To examine the hypotheses prospective teachers were investigated at the beginning, in the middle, and at the end of the practical phase of teacher education. The written lesson plans, videotaped lessons and transcribed oral reflections on the lessons were analysed using two different instruments which are described below. In addition self-evaluations of the prospective teachers as well as evaluations of the teacher educators and the mentoring teachers at school were collected. As every prospective teacher teaches different grades and topics, it was not possible to test the pupils' increase of knowledge.

The sample comprises twelve prospective teachers who provided data in all three sub-projects and six additional prospective teachers who provided their written lesson plans only. Ten of the twelve prospective teachers are female and they are 25 (SD = 1.168) years old on average.

Instrument of the Sub-Projects Planning and Conducting

The instrument to measure the abilities to plan and to conduct lessons is based on general criteria for high quality teaching as mentioned above and also includes criteria for high quality teaching in *Sachunterricht* (e.g. GDSU, 2013). It comprises six criteria which are differentiated in a divergent number of facets, see figure 2.

Criteria	Facets
Classroom Management	5
Clarity & Structure	8
Learning Environment	6
Activation	8
Supportive Classroom Climate	5
Handling Heterogeneity	5

Figure 2. Criteria and facets of the instrument

The facets are rated either dichotomously or on a four-point Likert scale. Based on Pietsch (2010) the six criteria were divided into two groups: A group of three criteria focussing the structure and organisation of a lesson (mid blue) that are assumed to develop earlier and a group of three criteria focussing the individual level of students (light blue) that are assumed to develop later.

The written lesson plans as well as the videotaped lessons were analysed by this instrument in a qualitative content analysis procedure (Mayring, 2000) using the software MAXQDA, see paragraph below. Despite the complex procedure the inter-rater agreements of the facets range between acceptable and perfect: $.640 < \kappa \leq 1.0$ for the written lesson plans and $.571 < \kappa \leq 1.0$ for the videotaped lessons. An expert rating with 17 experts for Sachunterricht proofed a high content validity of the instrument.

Instrument of the Sub-Project Reflection

The transcribed oral reflections were analysed regarding seven different criteria, see figure 3. Because the results focus on the *level of reflection* only this criterion is described here in detail: The transcripts were not analysed in whole but in segments, in which the prospective teachers talked about different aspects. They addressed a diverging number of aspects and all aspects were analysed and rated separately. For each aspect it was analysed whether it comprised a description of a key situation of the lesson, a rating of the key situation, a reason for the decisions and ratings, an alternative and consequences for the further development. When an aspect comprised all five elements it was rated on level five, when it comprised four it was rated on level four and so on, and it did not matter which four elements it comprised.

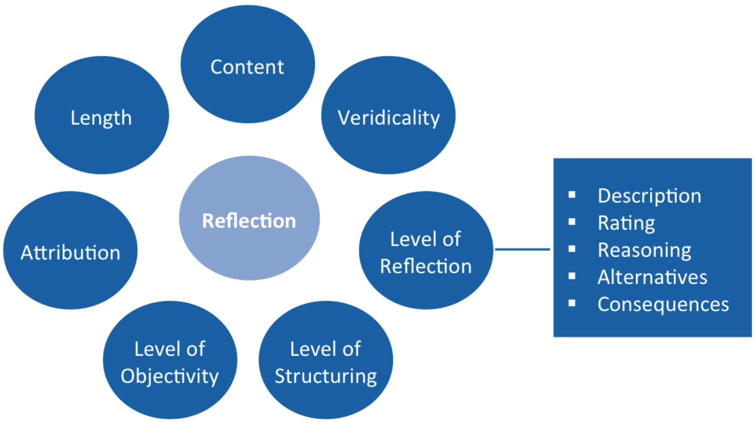

Figure 3. Criteria of the instrument

All reflections were double coded by two trained raters with a strong inter-rater agreement: $\kappa = .96$.

Methodological Approach: Qualitative Content Analysis

In the sub-projects Planning and Conducting the technique of structuring content analysis (Mayring & Fenzl, 2014) was applied. Since the instrument includes dichotomous as well as Likert scaled criteria, the procedure was a scaled structuring of the material. This is the most quantitative form of content analysis, which allows to incorporate quantitative methods in the analysis.

The theoretically derived categories were applied deductively. The application was carried out using coding guidelines (Mayring, 2000), which use anchor examples (positive indicators) as well as delimiting examples (negative examples). The analysis of the videotaped lessons based on standardized guidelines for qualitative content analysis according to Mayring & Fenzl (2014). It was divided into four analytical steps:

(1) watching the videotaped lesson in whole, making observation notes

(2) reviewing the appendix with photos of the classroom and copied materials

(3) watching and coding the videotaped lesson in 5-minute sequences

(4) coding finally by considering the steps 1-3

The context unit as the largest encodable unit was the entire lesson. Therefore, all low-inferent facets were coded in the form of an overall sampling (e.g. social arrangement) after step (1). All high-inferent facets (e.g. consistent use of rituals and routines) were assessed in the form of an overall sampling in step (4). Between these context units (1) and (4) are the smallest encodable units, named recording units. In this study the recording unit were either a working material or a photo or an event within the 5-minute sequences (e.g. dealing with disturbances).

RESULTS

Results of the Sub-Projects Planning and Conducting

Figure 4 shows the means (0-3) of the six criteria in both sub-projects planning and conducting as well as the 95 % confidence interval and the result of every single prospective teacher represented by a circle. The three criteria focussing the structure and organisation of a lesson (mid blue) are visible on the left, the criteria focussing the individual level of students (light blue) on the right hand side.

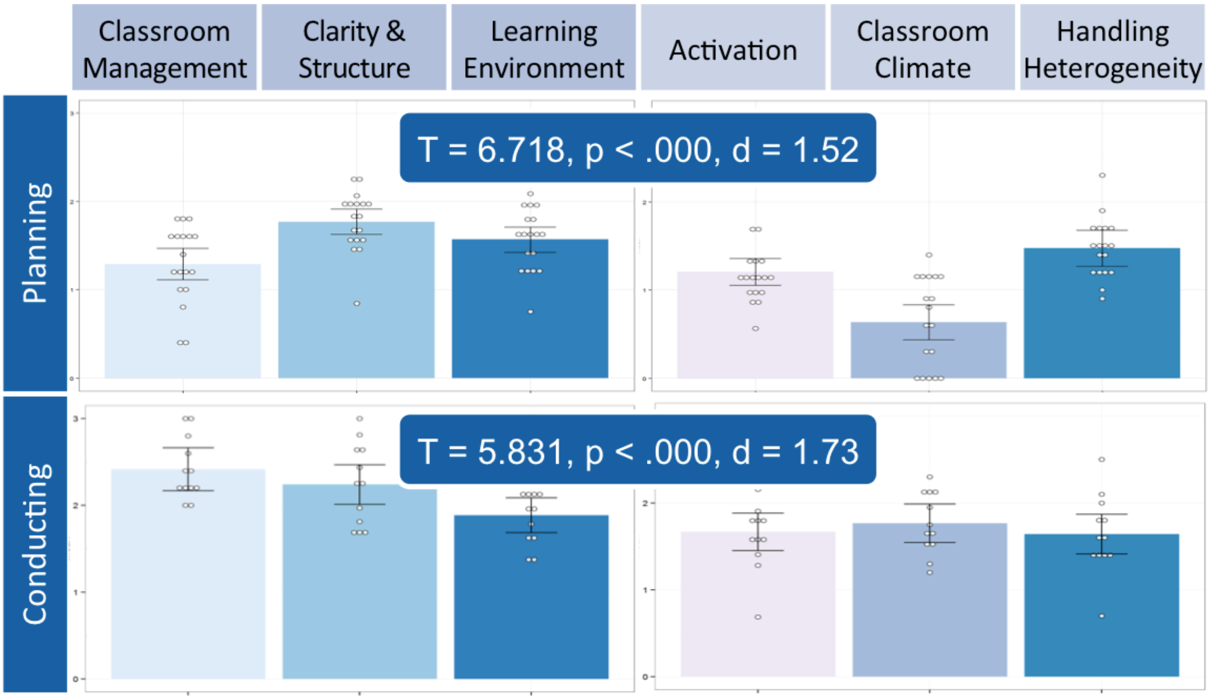

Figure 4. Results of the sub-projects planning and conducting

The prospective teachers have abilities to plan and conduct lessons in all six criteria at the beginning of the practical phase of teacher education. Only five prospective teachers showed no abilities in the criterion *classroom climate* in their written plan. There are large differences between the prospective teachers and a difference between the two groups of criteria as assumed. Two t tests show highly significant differences between the three criteria focussing the structure and organisation of a lesson vs. the three criteria focussing the individual level of students in both sub-projects. Non-parametric Wilcoxon tests confirm these significant differences. Furthermore, the results in conducting lessons tend to be higher than the results in planning lessons.

Results of the Sub-Project Reflection

Figure 5 shows the percentages of the five levels of reflection for all prospective teachers in total and for each of the twelve prospective teachers separately. In total 20 % of all aspects were rated on level 1; in the majority of the cases these aspects rated on level 1 were pure descriptions. 40 % of all aspects were rated on level 2, 30 % on level 3, 10% on level 4, and there were no aspects rated on level 5 at the beginning of the practical phase.

As in the two other sub-projects there are large differences between the prospective teachers: Some are able to reflect their lesson quite deeply and others only describe different situations. The level of reflection does not interrelate with the number of aspects the prospective teachers talked about as shown in figure 6.

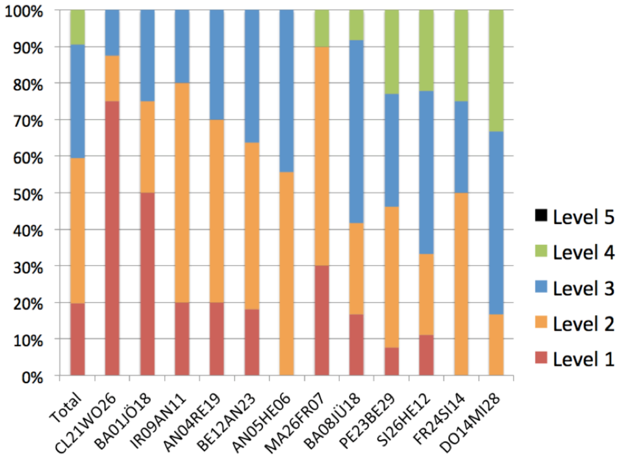

Figure 5. Percentages of the five levels of reflection

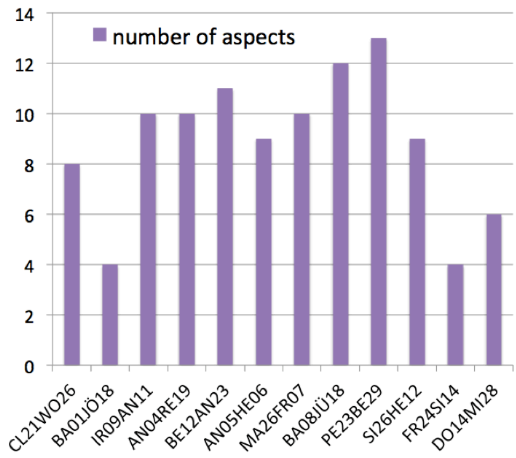

Figure 6. Number of aspects taken into account

DISCUSSION & OUTLOOK

The results show that prospective teachers have abilities in all criteria for high quality planning and conducting lessons at the beginning of the practical phase of teacher education. The scholarly phase of teacher education seems to address all criteria. The abilities in criteria focussing the structure and organisation of a lesson are higher than abilities in criteria focussing the individual level of students. This might be because the first ones are easier to learn than the latter ones. Other explanations might be that the first ones are a precondition for the latter ones or that the focus of the scholarly phase lies on the first ones. Furthermore, the results in conducting lessons tend to be higher than the results in planning lessons. On the one hand this might mean that it is easier for the prospective teachers to implement the criteria into their lessons than to describe them in their written plans. On the other hand it is possible that the implementation of some aspects is already a routine and prospective teachers do not see the necessity to describe them in the written plans.

The analyses of the reflection on lessons showed major differences in the abilities in reflecting on lessons at the beginning of the practical phase of teacher education, which do not interrelate with number of aspects taken into account. This means that the scholarly phase of teacher education has to address the reflection on lessons to enable all prospective teachers to use reflection for professional development from the beginning of the practical phase.

The limitations of the study lie in the small sample size. Therefore generalisation is not possible. However, the results are valuable to deduce hypotheses for further studies. They might be transferable to other teacher education systems than the one in Germany because they indicate which abilities prospective teachers have when they leave university. The results might also be transferable to other multi-perspective subjects than *Sachunterricht*, for example Science.

As a next step analyses of the development over the time of the practical phase of teacher education will be conducted. In this context further case-by-case-analyses seem reasonable to identify different types of development. Furthermore analyses of the dependencies between the three domains planning, conducting and reflecting on lessons will give interesting insights into the development. It might be that prospective teachers who reflect their lessons on a higher level, develop faster in planning and conducting lessons.

REFERENCES

Baer, M., Kocher, M., Wyss, C., Guldimann, T., Larcher, S., & Dörr, G. (2011). Lehrerbildung und Praxiserfahrung im ersten Berufsjahr und ihre Wirkung auf die Unterrichtskompetenzen von Studierenden und jungen Lehrpersonen im Berufseinstieg [Teacher Education and Experiences in Practical Phase in the First Professional Year and its Impact of the Instructional Competences of Students and Young Teachers at their Entry into the Profession]. *Zeitschrift für Erziehungswissenschaft, 14*(1), 85-117.

Blomberg, G., Renkl, A., Gamoran Sherin, M., Borko, H., & Seidel, T. (2013). Five research-based heuristics for using video in pre-service teacher education. *Journal for educational research online, 5*(1), 90-114.

Brophy, J. (2000). *Teaching*. Brussels: International Academy of Education & International Bureau of Education.

Dewey, J. (1933). *How We Think: A Restatement of the Relation of Reflective Thinking to the Educative Process.* Boston: D.C. Heath.

GDSU [Society for education in Sachunterricht] (2013). *Perspektivrahmen Sachunterricht [Perspective frame for Sachunterricht].* Bad Heilbrunn: Klinkhardt.

Hattie, J. (2009). *Visible learning: A synthesis of meta-analyses relating to achievement.* London: Routledge.

Helmke, A. (2009). *Unterrichtsqualität und Lehrerprofessionalität: Diagnose, Evaluation und Verbesserung des Unterrichts [Instructional quality and teacher profesionalism. Diagnosis, evaluation and improvement of instruction].* Seelze-Velber: Klett/Kallmeyer.

Kansanen, P. (2000). *Teachers' pedagogical thinking: Theoretical landscapes, practical challenges.* New York: Lang.

Mayring, P. (2000). Qualitative Content Analysis. *Forum Qualitative Research, 1*(2), Art. 20.

Mayring, P., & Fenzl, T. (2014). Qualitative Inhaltsanalyse [Qualitative content analysis]. In J. Blasius & N. Baur (Eds.), *Handbuch Methoden der empirischen Sozialforschung [Handbook of Methods in empirical social research]* (pp. 543–556). Wiesbaden: Springer VS.

Niemi, H. (2011). Educating student teachers to become high quality professionals - a Finnish case. *CEPS Journal, 1*(1), 43–66.

Pietsch, M. (2010). Evaluation von Unterrichtsstandards [Evaluation of teaching standards]. *Zeitschrift für Erziehungswissenschaft, 13*(1), 121–148.

Schön, D. (1983). *The reflective practitioner.* New York: Basic Books.

Slavin, R.E. (1994). Quality, Appropriateness, Incentive, and Time: A Model of Instructional Effectiveness. *International Journal of Educational Research, 21*, 141-157.

Viebahn, P. (2003). Teacher Education in Germany. *European Journal of Teacher Education, 20*(1), 87-100.

Wideen, M., Mayer-Smith, J., & Moon, B. (1998). A Critical Analysis of the Research on Learning to Teach: Making the Case for an Ecological Perspective on Inquiry. *Review of Educational Research, 68*(2), 130-178.

PRE-SERVICE SCIENCE TEACHERS' KNOWLEDGE, ATTITUDES AND ETHICAL APPROACHES REGARDING BIOTECHNOLOGY

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ABSTRACT

Biotechnology which is the fastest growing and most rapidly changing technology in the twenty-first century (Ravi, Baunthiyal, & Saxena, 2014). Even if biotechnology has great importance within the sciences, it is not still prominent field in the scope of science education (Borgerding, Sadler & Koroly, 2013). The purpose of this study was to investigate pre-service science teachers' (PST) content knowledge, attitude and ethical approach regarding biotechnology. A total of 275 PST attending to faculty of education at a mid-sized university in Turkey participated in the study. Data were collected through Content Knowledge about Biotechnology Scale (Prokop, Leškova, Kubiatko, & Diran, 2007), Attitudes towards Biotechnology Applications Scale (Özel, Erdogan, Uşak, & Prokop, 2009) and Ethical Approach to the Application of Biotechnology Scale (Yuce, 2011). Findings of the study indicated that PST generally have average content knowledge of biotechnology and a positive attitudes toward biotechnology applications. However, PST did not seem to support any biotechnological intervention used for living being. In addition, significant differences were not found in PST's mean scores of year at university and gender.

Key Words: Biotechnology, Pre-Service Science Teachers, Science Education

INTRODUCTION

Scientific literacy is one of the substantial purposes of science education (Goodrum, Hackling, & Rennie, 2001). Becoming scientifically literate has a place in individuals and societies to grasp new knowledge and use technological developments consciously (Özdemir, 2010). One of the most important advances in science and technology is biotechnology applications (Pardo, Midden, & Miller, 2002). Biotechnology which is the fastest growing and most rapidly changing technology in the twenty-first century has become a high science issue over a short period of time and generating totally a new yield that the organism cannot produce under normal conditions is possible with modern biotechnology (Ravi, Baunthiyal, & Saxena, 2014).

The main purposes of using biotechnology are to obtain products which change, develop and reproduce genetic structure of microorganisms, plants or animals (Babaoglu et al., 2001). Additionally, biotechnology involves three elements: living organisms, parts of organisms or components and specific processes or techniques (Wells, 1995). Biotechnology processes have great areas of utilization such as agriculture, sanitation, food industry and medicine (Davison, et al., 1997; Dawson, 2007) and also impact people life at some public areas such as hospitals, schools and universities (Chen & Raffan, 1999). Due to increasing impact of biotechnology in every aspect of our daily life, science educators have an important role to play in the development of better informed students with specific attitudes, skills and education regarding the use and development of biotechnology (Wells, 1992, 1994).

While some useful influences of biotechnology processes make our lives easier, some of them can be used for malicious purposes such as biological weapons and genetically modified plant and animal foods (Brainard, 2005). Uncertainty and risks about biotechnology has brought several questions and this situation has caused to some controversies related to ethics (Samancı, 2009). Ethics defines all objectives and actions clearly and set forth things which are needed to do (Aydın, 2003). Besides, ethics are not only about individuals but also all of society (Yurtseven, 2000). Ethical behaviors are rule of a thumb in order to distinguish right and wrong or good-bad (Akdoğan, 2000). One more concept related to ethics in literature is bioethics that was born in the 1960’s (Gross, 2014). The meaning of bioethics has been defined by many researchers (e.g., Eubios; 2005; Mepham, 2005; Potter, 1971; Reiss, 2002; Woods & Elstein, 2003). In the light of the concepts of ethics and morality, bioethics is an area where the ethical issues are addressed pertaining to human health and other biological sciences (Kushe & Singer, 2001.)

Ethical responsibilities that arise as a result of biotechnological studies are not only limited with ethicists, scientists, physicians, specialists, technicians or other persons involved in the field of life sciences, but responsibility for bioethical issues also bears upon legislators, decision-makers and whole society (Surmeli, 2008). Some moral and ethical situations that arise at biotechnology applications cause mainly concern with regards to security, risk, uncertainty and commercial maintenance (Yuce, 2011). Furthermore, in the consequence of biotechnology applications, some scientific developments occurred such as artificial insemination, DNA profiling, embryonic stem cell, euthanasia, gene transfer, genetically modified organisms, genetic screening methods, proteomics, biosensors, human genome project (HGP), organ, tissue and cell donation and reproductive cloning (Çobanoğlu, 2009; Lysaght, Rosenberger & Kerridge, 2006; Ravi et al., 2014) and these developments have been elicited some important ethical issues with respect to animal rights, divulgence, privacy, abuse, unforeseen damage, public order, professional conduct, forming toxic and allergic effects with regard to the microbial production, risks about environment, transgenic food, resource allocation, rights over intellectual (Bhatia, 2005; Bryant, Baggott la Valle, & Searler, 2005; Charlesworth, 1989; Menikoff, 2002; Pieper, 1999).

In order to deal with concerns regarding the application of biotechnology, UNESCO accepted universal declaration on bioethics and human rights which includes human dignity, human rights and fundamental freedoms in 2005. Additionally, similar to UNESCO declaration, some legislation such as “Gene Technology Act” in 2000 and “the Prohibition of Human Cloning Act” and “the Research Involving Human Embryos Act” in 2002 were enacted in Australia (Lysaght, Rosenberger & Kerridge, 2006).

Major reform efforts in science education have included much discourse about the importance of developing students’ literacy in science. As part of the growing effort to help students in becoming scientifically literate, biotechnology has been an accepted as an important content area in science education. The importance of biotechnology education has been recognized in a number of national curriculum frameworks including Turkish science curriculum. However, previous studies with pre-university students indicated positive attitude toward biotechnology and attitude can be improved positively with appropriate teaching methods. The results of one study conducted by Chen and Raffan (1999) indicated that almost all students thought biotechnology provide opportunities for the new products and students with higher grade had more positive attitudes toward biotechnology than lower grade. In Lock, Miles, and Hughes’ (1995) study, a teaching program was conducted to 16-year-old students to investigate effectiveness of the program on their knowledge and attitudes toward biotechnology. In the result of study, students’ knowledge increased significantly and their attitudes became more positive. In one of the researches related to teaching biotechnology, Zeller (1994) aimed to understand how biotechnology instruction affect high school students’ attitude toward biotechnology and he taught biotechnology for 15 days. Results of the study revealed as time progressed, students’ attitudes became more positive.

Science education have endeavored in recent years to incorporate biotechnology content into science classrooms, but the actual implementation of biotechnology instruction remains insufficient (e.g., Leslie & Schibeci, 2006). Several studies reported that deficiencies in teachers' professional development, knowledge and the administrative support needed to teach biotechnology (Dawson, 2007; Leslie & Schibeci, 2006; Steele & Aubusson, 2002; Wilson et al., 2002). Biotechnology with many dimensions-scientific, technological, sociological, and ethical seemed to be particularly complex area for the teachers. For that reason, teachers have some difficulties about how to approach the teaching of this subject and how to manage students' responses (Michael, Grinyer, & Turner, 1997, Moreland, Jones & Cowie, 2006). In Prokop, Lešková, Kubiatko and Diran' (2007) study, pre-service teachers' knowledge and attitudes toward biotechnology was investigated. The results of the study revealed that Slovakian pre-service teachers had poor knowledge, additionally, males had a more positive attitude than females. Besides, there were positive and significant correlation between the knowledge level and attitudes. Similarly, Chabalengula, Mumba and Chitiyo (2011) also found that pre-service teachers' attitudes towards biotechnology were high. If it is needed to show in detail, while many of them supported genetic modification related to microorganisms and plants, they didn't approve genes insertion to humans and animals. Different from those, Yuce (2011) focused not only on knowledge and attitude of pre-service science teachers (PSTs) but also bioethics. In the result of this study, it was appeared that their scientific knowledge level was average. For example, while Sheep Dolly was known widely by PSTs, the meaning of the transgenic word wasn't explained explicitly. Moreover, 70 % of them believed that biotechnology applications include some drawbacks in terms of ethical approach such as religious aspects, deterioration of the natural order and human health. One more study conducted by Surmeli and Sahin (2012), with regard to bioethics, revealed that PSTs' attitudes toward genetic testing and genetic diagnosis were positive as well.

Determination of science education curriculum is under the responsibility of *'Council of Higher Education'* that coordinates all higher education institutions in Turkey. In the department of science education, PSTs encounter with biotechnology in some courses related to the biology such as "General Biology", "Genetics and Biotechnology" and "Specific Issues in Biology". In the course of "General Biology", pre-service teachers are given basic concepts. However, biotechnology involves in the following two courses in detail (Kılınç, Kartal, Eroglu, Demiral, Afacan, Polat, Demirci, & Görgülü, 2013): 'Genetics and Biotechnology' course includes chromosomes and heritage, genetic engineering and its effects on society and basic rules of biotechnology, human genetics and genetic illnesses, molecular biology and concepts of genes topics and 'Specific Issues in Biology' course includes cloning, Nano biology, GM organisms, recent developments in biology such as stem cell technology and the importance of biology for society.

In the department of science education, curriculum composes of not only science and biology subjects but also it includes pedagogical content knowledge courses such as *'Special Teaching Methods'*, *'Principles and Methods of Teaching'*, *'School Experience'* and *'Teaching Practice'* to transfer knowledge in the best way. Individuals who will be teacher must have some competencies consisting of pedagogical knowledge and knowledge of educational context in addition to content knowledge (Magnusson et al., 1999).

In addition to teachers' adequate understanding of biotechnology, teachers' self-efficacy beliefs regarding biotechnology teaching has been another important construct influencing implementation of biotechnology instruction. One more concept related to education is self-efficacy. This concept is defined as teachers' belief in their own capability to arrange and carry out courses require action to accomplish a specific instructing task in a special situation successfully (Tschannen-Moran, Hoy & Hoy, 1998). Research has consistently showed a strong relationship between teacher efficacy, positive teaching behavior, and student outcomes. Teacher efficacy is related to teachers' effort and persistence in the face of difficulties (Ashton & Webb; Gibson & Dembo, 1984; Soodak & Podell, 1993), professional commitment (Coladarci, 1992; Evans & Tribble, 1986), openness to instructional innovations (Allinder, 1994; Guskey, 1988), students' motivation (Midgley, Feldlaufer, & Eccles, 1989), and efficacy beliefs (Anderson, Greene, & Loewen, 1988). Research indicated that teachers with high efficacy tended to use inquiry and student-centered teaching strategies, while teachers with a low efficacy are more likely to use teacher-directed strategies, such as didactic lectures and reading from textbooks (Czerniak, 1990).

Even if biotechnology has great importance within the sciences, it is not still prominent field in the scope of science education (Borgerding, Sadler & Koroly, 2013). Importance of teaching the subject of biotechnology is to inform scientific and technical characteristics of biotechnology to students in a tangible way (Yuce, 2011). Regarding biotechnology education, Surmeli and Sahin (2012) stated that "Young people need to be informed, not only about the practical applications of biotechnology, but they also need to appreciate the social and bioethical implications" (p.77).

In the literature pertaining to biotechnology involved in science education, researchers focused on mainly the following research themes: attitude and knowledge toward biotechnology, the relationship between these two themes and effects of biotechnology instruction on them (e.g., Chabalengula, Mumba & Chitiyo, 2011; Chen & Raffan, 1999; Dawson & Schibeci, 2003; Dawson & Soames, 2006; Dawson, 2007; Fonseca et al., 2012; Gunter et al., 1998; Kidman, 2009; Klop & Severiens, 2007; Levitt, 1999; Lock & Miles, 1993; Lock, Miles & Hugles, 1995; Olsher & Dreyful, 1999; Pouris, 2003; Prokop et al., 2007; Tikka, Kuitunen & Tynys, 2000; Usak et al., 2009; Weaver, 2002). Apart from these, several researchers conducted bioethics-oriented studies (e.g., Keskin, Samancı & Kurt, 2013; Levinspn, 2004; Samancı, 2009; Surmeli, 2010; Surmeli & Sahin, 2012; Yuce, 2011).

In spite of the many background studies supporting importance of biotechnology education (e.g., Savage & Sterry, 1990; Wells, 1992, 1994), it has received less attention in pre-service teacher education focusing their ethical approach and teaching self-efficacy beliefs regarding biotechnology.

Purpose and Research Questions

The purpose of this research is to investigate pre-service science teachers' (PSTs) content knowledge, attitude, ethical approach and teaching efficacy beliefs regarding biotechnology. There are three research questions guided the study:

- What are the pre-service science teachers' content knowledge, attitudes, ethical approaches and teaching self-efficacy beliefs toward biotechnology?
- Are there any differences at gender and year in the university with respect to pre-service science teachers' knowledge, attitudes, ethical approach and teaching self-efficacy beliefs?

METHODS

Sample

A total of 275 PSTs (28% male 72% female, mean age = 20.70 years) attending to faculty of education in a mid-sized university in Turkey were involved in the study. The sample consisted of 60 freshman, 68 sophomore, 82 junior and 65 senior. The sample of this study was determined with convenience sampling. The most fundamental feature of convenience sampling is that researchers can easily reach sample (Fraenkel, Wallen, & Hyun, 2012).

Instruments

Data were collected through Self-Efficacy Beliefs Scale (Kılınç et al., 2013), Content Knowledge about Biotechnology Scale (Prokop, Leškova, Kubiatko, & Diran, 2007), Attitudes towards Biotechnology Applications Scale (Erdogan, Özel, Uşak, & Prokop, 2009) and Ethical Approach to the Application of Biotechnology Scale (Yuce, 2011). Further information about these scales is given in Table 1. Additionally, five demographics questions regarding age, gender, year in the university, whether they get course about biotechnology and religious and ideological views were also asked to the participants.

Table 1

Name of Questionnaire, Alternative Responses and Item Sources

Questionnaire	Alternative Reponses	Item Source
Self-Efficacy Beliefs (SEBS)	Never (1) Too little Some Rather Much (9)	Kılınç et al. (2013)
Content Knowledge about Biotechnology (CKBS)	True, False I don't know	Prokop et al. (2007)
Attitudes towards Biotechnology Applications (ABAS)	I strongly agree I agree, I neither agree nor disagree I disagree I strongly disagree	Erdogan et al. (2009)
Ethical Approach to the Application of Biotechnology (EAABS)	I strongly agree I agree, I neither agree nor disagree I disagree I strongly disagree	Yuce (2011)

Self-Efficacy Beliefs Scale (SEBS)

SEBS was used in this study in order to examine the participants' self-efficacy beliefs regarding teaching biotechnology. Since this scale originally was developed to examine self-efficacy beliefs for teaching GMO (Kılınç et al., 2013), necessary revision and adoption for the topic of biotechnology was done. In order to determine the reliability and validity of the scale, pilot study was conducted with 180 PSTs (17.8 % male, 80.2% female; mean age =20.44). So as to understand whether SEBS is appropriate for factor analysis, KMO and Barlett test results were analyzed. If KMO is .6 or upper and Barlett value is 0.5 or below, test is suitable for factor analysis data (Pallant, 2005). As a result of the analysis, KMO test value is .80 and Bartlett test value is .000. According to results of factor analysis, SEBS was formed of two subdimensions. These subdimensions are called as 'Grasping topic' (7 items) and 'Provision of student interest' (9 items). The final version of the SEBS consists of 16 items and each of these items has 9 responses ranging from "Never" to "Much". The alpha reliability of SEBS was found to be .87. Alpha reliabilities of the 'Grasping topic' and 'Provision of student interest' were .68 and .91 respectively.

Content Knowledge about Biotechnology Scale (CKBS)

CKBS is a 16 item with 3 responses instrument. The available responses are “True”, “False” and “I don’t Know”. This scale was adapted into Turkish by Ozel et al. (2009). Cronbach alpha coefficient for the scale was found to be .62.

Attitudes towards Biotechnology Applications Scale (ABAS)
ABAS developed by Erdogan et al. (2009) consists of 25 items. This scale originally was formed as 6 subdimensions: ‘Shopping of GM products’ (6 items), ‘Public awareness of GMO’ (3 items), ‘GM in agro industry’ (5 items), ‘Use of genetic engineering in human medicine’ (3 items), ‘Ecological impact of genetic engineering’ (4 items) and ‘Consumption of GM products’ (4 items). The available responses for these items were “I strongly agree”, “I agree”, “I neither agree nor disagree”, “I disagree” and “I strongly disagree”. The reliability of scale was found to be .82.

Ethical Approach to the Application of Biotechnology Scale (EAABS)
EAABS developed by Yuce (2011) is composed of 22 items. This scale originally consisted of 7 subdimensions: ‘Attitude toward GMO’ (3 items), ‘Biotechnology applications related with people’ (3 items), ‘Changing genetic structure of living being’ (4 items), ‘Changing genetic structure of plants’ (2 items), ‘Consumption of GMO’ (3 items), ‘Creating baby’ (4 items) and ‘Transfer between the genes of humans and animals’ (3 items). Responses in this part were “I strongly agree”, “I agree”, “I neither agree nor disagree”, “I disagree” and “I strongly disagree”. The reliability of scale was .70.

Data Collection
The data were collected in 2013-2014 fall semester within a month. Before collecting data, the permissions were got from universities and participants. During implementation of the study, the first author took in charge in order to provide consistency of procedure and the questionnaires took 30 minutes to complete.

Data analysis
This study comprises three kinds of statistical analysis. Descriptive statistics and two way multivariate analysis of variance (MANOVA) in order to test for differences in terms of gender and year in university were conducted. Finally, in order to predict teacher efficacy beliefs, multiple regression analysis was used.
Prior to two way MANOVA analysis, it was tested whether data conform to the assumptions consisting of homogeneity of variance-covariance matrices, independence of observations and multivariate normality as Pallant (2005) recommended. Besides, there are some assumptions belong to multiple regression such as multicollinearity, outliers, linearity, homoscedasticity, and independence of residuals. The results of the statistical processes indicated that assumptions toward both of the analyses were verified successfully.

RESULTS

The majority of participants (74%) stated that they didn’t get any course about biotechnology during university life. When their ideological or religious situation was examined, it was seen that while the proportion of conservative PSTs was the highest level (39,3 %), the lowest level belongs to liberal (1,5 %).

PSTs’ Content Knowledge about Biotechnology
Among 16 items, eight were answered correctly by more than 50%, while remaining eight items were answered correctly by 48 % of PSTs. Basic content knowledge pertaining to biotechnology was generally known. For example, three quarters of the PSTs were conscious

that application of biotechnology methods on animals and plants can increase resistance against diseases. Similarly, correct answers were obtained substantially with regard to some issues such as use in medicine, genes of GM organisms can be changed with manipulation of DNA and human genes are not damaged because of consumption of GM food. However, some items were incorrectly responded substantially. For example, two-thirds of PSTs believed that GM organisms are always bigger than normal. Similarly, only one third of them thought that GM organisms don't contain dangerous chemicals and genetic modification is not painful for animals. In addition to items about risk aspects of biotechnology, majority of PSTs gave wrong answers to some items containing specific concepts such as somatotropin as well. Findings toward PSTs' content knowledge about biotechnology are displayed in Table 2.

Table 2
Items of Content Knowledge about Biotechnology Scale

	Scale Items	Correct Answer	Responded correctly (%)
1	Application of GM methods on animals can increase animal resistance against diseases	True	74
2	GM organisms are used in medicine (e.g., insulin production with GM microorganisms)	True	75
3	Practical application of GM plants may increase productivity and resistance of plants against diseases	True	73
4	GM organisms are always bigger than normal	False	39
5	Microbes should be genetically engineered to make them more efficient at decomposing human sewage	True	50
6	Genetic modification to plants can increase nutritional quality and flavour of fruits and develops traits to withstand shipping process	True	52
7	Foods with increasing nutritional value and vitamins can be created through genetic modification	True	48
8	GM organisms contain many dangerous chemicals	False	30
9	Genetic modification is painful for animals	False	27
10	It is possible to transfer genetic material between dissimilar organisms, such as animals and plants, because DNA is chemically identical	True	38
11	GM modification of poultry results in greater proportion of lean	True	35
12	Manipulation with DNA changes genes of GM organisms	True	67
13	Consumption of GM food can destroy human genes	False	68
14	GM crops are sterile	False	61
15	Porcine somatotropin is a hormone active in hogs that directs dietary energy away from fat disposition toward production of lean muscle	True	23
16	Recombinant bovine somatotropin is an animal drug that increases milk produced by dairy cows	True	16

PSTs' Attitudes toward Biotechnology Applications

Table 3 lists descriptive statistics for the subdimensions of ABAS. For this scale, the mean scores higher than 3 are accepted as higher mean scores whereas the mean scores lower than 3 are accepted as lower mean scores. The highest and lowest mean scores were yielded by 'use of genetic engineering in human medicine' subdimension (M = 3.57) and 'consumption of GM products' subdimension (M = 0.96). These values show that PSTs have negative attitudes toward biotechnology at high rates.

Table 3

Name of the Factors Related to Attitudes towards Biotechnology Applications

Factors	*M*	*SD*
Shopping of GM products	2.12	.827
Public awareness of GMO	2.72	.818
GM in agro industry	3.41	.681
Use of genetic engineering in human medicine	3.57	.817
Ecological impact of genetic engineering*	1.29	.787
Consumption of GM products*	0.96	.950

* Negatively worded items are reversed.

Table 4 lists the mean scores, standard deviations and percentages of respondents along the subdimensions of ABAS. Considering items in detail, about three quarters of PSTs stated that they don't accept altering the genes in fruit to improve their taste. At a similar rate, they are against altering the genes of fruits and vegetables to make them stay fresh longer. Almost one-tenth of them believed that consumption of genetically modified food has no risk. Additionally, PSTs don't support applications of biotechnology on the ecology. For example, over half of them (66%) thought that ecological relationships are disturbed by genetic manipulations and they supported legislating against production and purchase of genetically engineered products (63%). Biotechnology applications on agro industry were supported in some cases such as recovering from genetically determined diseases by about three quarters of PSTs (%71). Additionally, they were curious and wanted to learn much more things about the use of biotechnology applications in agriculture (75%). However, one-third of them were hesitant in some items such as changing plant's genetic structure to be more resistant to damage by insects (33%), using plants to increase quality and productivity of genes (31%). PSTs awareness toward biotechnology was generally moderate. For example, one-third of PSTs stated that they trust food industry to take the necessary measures (31%) while one-quarter of PSTs don't trust (25%). Moreover, their views were uncertain (46%). Besides, almost half of them were not sure whether governmental regulations are sufficient (42%). More than half of them believed that public is not sufficiently informed about risks of biotechnology applications (64%). One important issue in biotechnology applications PSTs supported is shopping of them. Majority of them stated that these foods influence human health (68%) and they can buy (73%) and eat (60%). When it comes to human medicine, more than half of them found biotechnology useful in some situations such as production of human medicines (61%).

Table 4

Mean Scores, Standard Deviations and Percentages of Respondents along the Subdimensions of ABAS Items.

Subdimensions	Item	*M*	*SD*	Agree* (%)	Disagree* (%)
Consumption of GM products**	1	0.97	1.20	13,4	71,6
	2	0,96	1.20	15,5	72,4
	3	1,08	1.10	12,4	70,5
	7	0,80	1.13	11,6	77,4
GM in agro industry	8	3.95	1.11	70,6	11,6
	15	3.05	1.23	38,2	30,2
	16	2.88	1.12	29,1	33,8
	18	3.07	1.22	38,2	30,5

	25	4.13	1.19	74,9	11
Public awareness of GMO	22	3.06	1.12	30,9	25,3
	23	2.76	1.08	21,1	36,7
	24	2.35	1.30	21,1	63,6
Shopping of GM products	9**	2.07	1.15	68,3	12,4
	10	2.27	1.18	18,5	60,2
	11	2.01	1.13	13,4	70,4
	12	1.99	1.12	11,3	73,3
	13	2.17	1.09	10,9	62,0
	14	2.28	1.20	17,4	59,2
Ecological impact of genetic engineering**	17	1.57	1.26	26,4	50,5
	19	1.19	1.17	15,5	64,4
	20	1.17	1.03	10,3	66,2
	21	1.19	1.15	14,9	62,6
Use of genetic engineering in human medicine	4	3.44	1.10	49,1	18,5
	5	3.67	1.10	60,7	15,2
	6	3.53	1.08	51,6	15,8

*Data show combined percentages of pre-service science teachers who ‘strongly agree’ or ‘agree’.

**Items were reverse scored.

PSTs’ Ethical Approaches to the Applications of Biotechnology

This section that related to biotechnology applications has seven factors which were obtained from original study. Factors are given in Table 5.

Table 5

Name of the Factors Related to Ethical Approach to the Application of Biotechnology

Factors	Min	Max	Mean	Std. Dev
Attitude Toward GMO	1,00	5,00	2,12	,87949
Biotechnology Applications which is on People	1,00	5,00	2,65	,68330
Changing Genetic structure of living being*****	1,00	5,00	2,37	,77414
Changing Genetic structure of Plants	1,00	5,00	1,98	,89641
Consumption of GMO	1,00	5,00	2,51	,79266
Creating Baby	1,00	5,00	2,45	,87470
Transfer between The Genes of Humans and Animals	1,00	5,00	3,33	,79210

* Negatively worded item is reversed.

When ‘*Ethical Approach to the Application of Biotechnology’* is examined, it is seen that pre-service science teachers don’t support any intervention to living being using biotechnological process. This could be because proportion of conservative participants is high. In terms of factors, results are shown in detail in below.

Pre-service science teachers has negative ‘*attitude toward GMO*’. They think that risk occurs if organisms release to nature uncontrolled. Moreover, they consider foods that obtained by genetic changes should be informed and there is negative effect in consumption plant and animals which are changed in terms of genetics. Participants don’t support ‘*changing genetic structure of living being’*. They think people have no right to changing nature of living being in order that they gain favor to their selves and they are anxious emerging new illness using biotechnological products unconsciously**.** Participants have not exactly stable view toward ‘*Biotechnology Applications which is on People’* such as limited with law. Additionally, they don’t support studies related to human reproduction. Similar results to people, ‘*Changing*

Genetic structure of Plants' is not supported. Moreover, pre-service science teachers don't genetically modified fruit is more delicious than not genetically modified fruit and they consider risky about consumption fruit and vegetables which are GMO. '*Consumption of GMO'* is not supported as well. According to participants, changing genetic structure of animal couldn't be changed for human nutrition and foods which produced with biotechnological process are not reliable for consumption. Pre-service teachers don't support reproduction animals to prevent famine matter. In terms of '*Creating Baby',* as previous results factors show, this one is not supported by participants who think also during embryo, if a baby is handicapped, its life shouldn't be ended with abortion. Biotechnology is used not only handicapped baby but also healthy baby. In terms of intelligence and personality, especially for creating excellent gene biotechnology process shouldn't be applied. '*Transfer between the Genes of Humans and Animals'* is not correct behavior for participants. In the same time, they think producing human protein at sheep milk via transferring genes of sheep to people is not correct. However, there are some items which participants are undecided. One of them is related to transplantation. For example, in some process, human stem cells transfer to animal fetus in venter. In this situation, pre-service science teachers decided neither agree nor disagree. The reason why this undecided situation occurs may be because they can't depict transfer process completely and can't understand. They may not know meaning of some words such as stem cell, animal fetus, and venter.

Differences in Gender and Year at University

Two way MANOVA was used in order to test for differences in gender and year at university with respect to PSTs' knowledge, attitudes, ethical approach and teaching self-efficacy beliefs.

According to analysis of two way MANOVA, statistically significant differences were not found in PSTs' mean scores of year at university (Wilks' λ = .91, $F(3, 192) = 1.24$, $p = .25$) and PSTs' mean scores of gender (Wilks' λ = .98, $F(3, 192) = .63$, $p = .64$). Findings toward this analysis are displayed in Table 6.

Table 6

Investigation of Significant Difference in the Variables of Year at University and Gender

Variables	Wilks' λ	F	p*	η^2
Year at University	,91	1,24	,25	,030
Gender	,98	,63	,64	,016

DISCUSSION AND CONCLUSION

According to the results of this study, although PST had insufficient knowledge about genetically modified plants, ingredients of GM organisms such as '*containing many dangerous chemicals*' and effect of GM organism on living beings such as '*painful for animals*, their content knowledge of biotechnology was adequate. However, in similar studies performed in Turkey, it was found that participants generally have a low level of knowledge (Darçın & Türkmen, 2006; Türkmen & Darçın, 2007; Özel et al., 2009). In Slovakia, Prokop et al. (2007) also reported that pre-service teachers have low level knowledge about biotechnological operations. Present study also indicated that PSTs have a positive attitude toward biotechnological applications unless they are used for living being. Surmeli and Sahin (2010) who investigated undergraduates' bioethics views about genetic engineering also obtained similar results. The role of teachers is of great importance in equipping students with knowledge about biotechnology. For that reason, teacher education programs in Turkey need to find ways to enhance PST' knowledge level of and attitude toward biotechnology.

REFERENCES

Borgerding, L. A., Sadler, T. D., & Koroly, M. J. (2013). Teachers' concerns about biotechnology education, *Journal of Science Education and Technology, 22,* 133–147. doi: 10.1007/s10956-012-9382-z.

Cakiroglu, J., Aydın, Y., Hoy, A., W. (2012). Science teacher learning, In B. J. Fraser, K. G. Tobin & C.J., McRobbie (Eds.), *Second International Handbook of Science Education,* (pp. 449-461). New York: Springer.

Chabalengula, V. M., Mumba, F., Chitiyo, J. (2011). American elementary education pre-service teachers' attitudes towards biotechnology processes. *International Journal of Environmental & Science Education,6(*4*), 341-357.*

Chen, S. Y., & Raff an, J. (1999). Biotechnology: Student's knowledge and attitudes in the UK and Taiwan. *Journal of Biological Education*, *34* (1), 17-23.

Darcın, E. S., & Turkmen, L. (2006). A study prospective Turkish science teachers' knowledge at the popular biotechnological issues. *Asia Pacific Forum on Science Learning and Teaching, 7*(2).

Dawson, V. & Schibeci, R. (2003). Western Australian high school students' attitudes toward biotechnology processes. *Journal of Biological Education, 38*(1), 7–12.

Dawson, V. & Soames, C. (2006). The effect of biotechnology education on Australian high school student‟s understandings and attitudes about biotechnology processes. *Research in Science and Technological Education, 24* (2), 183-198.

Dawson, V. (2007). An exploration of high school (12-17 year old) students' understandings of, and attitudes towards biotechnology processes. *Research in Science Education, 39,* 59-73.

Fonseca, M. J., Costa, P., Lencastre, L., & Tavares, F. (2012). Disclosing biology teachers' beliefs about biotechnology and biotechnology education, *Teaching and Teacher Education*, 28, 368-381

Goodrum, D., Hackling, M., & Rennie, L. (2001). *The status and quality of teaching and learning of science in Australian schools*. A research report prepared for the department of education, training and youth affairs. Retrieved from http://www.dest.gov.au/sectors/school_education/publications_resources/science_in_australian_schools/documents/sciencereport_pdf.htm

Gunter, B., Kinderlerer, J. & Beyleveld, D. (1998). Teenagers and biotechnology: a survey of understanding and opinion in Britain. *Studies in Science Education, 32,* 81–112.

Keskin, M. Ö., Samancı, N. N., & Kurt, İ. (2013). The investigation of the opinions of teacher candidates about current ethical issues in terms of various variables, *Journal of Higher Education and Science, 3(*2*), 142-152.*

Kidman, G. (2009). Attitudes and interests towards biotechnology: the mismatch between teachers and students. *Eurasia Journal of Mathematics, Science and Technology Education,* 5 (2), 135-143.

Kılınç, A., Kartal, T., Eroglu, B., Demiral, U., Afacan, Ö, Polat, D., Demirci Güler, M.P., Görgülü, Ö. (2013). Preservice science teachers' efficacy about a socioscientific issue: A belief system approach. *Research in Science Education. doi:* 10.1007/s11165-013-9368-8

Leslie, G. & Schibeci, R. (2006). Teaching about designer babies & genetically modified foods: Encouraging the teaching of biotechnology in secondary schools. *The American Biology Teacher, 68*(7), 98-103.

Levitt, M. (1999) Drawing Limits: contemporary views on biotechnology, *Journal of Beliefs & Values: Studies in Religion & Education,* 20:1, 41-50, http://dx.doi.org/10.1080/1361767990200104.

Liu, X. (2009). Beyond science literacy: Science and the public. *International Journal of Environmental & Science Education. 4*(3), 301-311.

Lock, R. & Miles, C. (1993). Biotechnology and genetic engineering: students' knowledge and attitudes. *Journal of Biological Education, 27*(4), 267-273.

Michael, M., Grinyer, A. and Turner, J. (1997). Teaching biotechnology: identity in the context of ignorance and knowledgeability. *Public Understanding of Science, 6,* 1-17.

Moreland, J., Jones, A., & Cowie, B. (2006). Developing pedagogical content knowledge for the new sciences: The example of biotechnology. *Teaching Education, 17*(2), 143-155.

Ozcan S, Gurel E, Babaoglu M (2001) Plant Biotechnology, Genetic Engineering and Its Applications, Selcuk University Press, Konya, Turkey

Özdemir, O. (2010). Fen ve teknoloji öğretmen adaylarının fen okuryazarlığının durumu**.** *Journal of Turkish Science Education, 7*(3), 42-56.

Özel, M., Erdoğan, M., Uşak, M., & Prokop, P. (2009). High school students’ knowledge and attitudes regarding biotechnology applications. *Educational Sciences: Theory & Practice, 9*(1), 297-328.

Pardo, R., Midden, C., & Miller, J. (2002). Attitudes toward biotechnology in the European Union. *Journal of Biotechnology*, *98*(1), 9-24.

Pieper, A. (1999). *Introduction to Ethics*. İstanbul: Ayrıntı

Pouris, A. (2003).Assessing public support for biotechnology in South Africa. *South African Journal of Science,* 99(11/12), 513-516.

Prokop, P., Leskova, A., Kubiatko, M. & Diran, C. (2007). Slovakian student’s knowledge of and attitudes toward biotechnology. *International Journal of Science Education, 29*(7), 895- 907.

Ravi, I., Baunthiyal, M., & Saxena, J. (2014). *Advances in biotechnology*. London: Springer.

Steele, F. & Aubusson, P. (2004). The challenge in teaching biotechnology. *Research in Science Education, 34,* 365-387.

Stephen Thomas Garrett. (2009). Professional Development for the Integration of Biotechnology Education, Queensland University of Technology, Masters thesis.

Surmeli, H. & Sahin, F. (2010). Üniversite öğrencilerinin genetik mühendisliği ile ilgili biyoetik görüşleri: Genetik testler ve genetik tanı. *Journal of Turkish Science Education, 7*(2), 119-132.

Sürmeli, H. (2008). Üniversite öğrencilerinin biyoteknoloji ve genetik mühendisliği çalışmaları ile ilgili tutum, bilgi ve biyoetik görüşlerinin değerlendirilmesi, Marmara University, Institute of Education Sciences, PhD Thesis, İstanbul, Turkey, pp 392.

Tschannen-Moran, M., Woolfolk Hoy, A., & Hoy, W. K. (1998). Teacher efficacy: Its meaning and measure. *Review of Educational Research, 68,* 202–248.

Turkmen, L., & Darcın, E. S. (2007). A comparative study of Turkish elementary and science education major students’ knowledge levels at the popular biotechnological ıssues.

Yüce, Z. (2011). *Pre-service science teachers’ knowledges about biotechnology and their bioethic approaches towards biotechnology practices: Attitudes, views and values* (master’s thesis), Gazi University, Ankara, Turkey.

DOMAIN-SPECIFIC TEACHERS' COMPETENCIES (FALKO) – SUB-PROJECT PHYSICS

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Abstract:

Empirical studies such as the COACTIV-study show that one factor of effective school education is being a good teacher. However, it has still not been sufficiently clarified of which specific competencies a teacher makes use of while teaching. In order to identify these competencies, national as well as international researchers have been trying to theoretically establish and empirically measure such competencies by using various types of tests. Therefore, the research group FALKO (University of Regensburg, Germany) has the aim to create paper-and-pencil-tests in order to quantify subject-specific professional knowledge, which is said to be one of the central competencies of a teacher. Once finished, the tests should be able to be applied on secondary school teachers. The development of the tests is based on a common theoretical framework derived from Shulman's taxonomy and the COACTIV-study. The test of the sub-project FALKO-physics focuses on the content knowledge (CK) and the pedagogical content knowledge (PCK) as parts of the professional knowledge of teachers. While the CK-items deal with the topics taught on the junior and the senior high-school-level (mechanics, electricity, thermodynamics, optics), the PCK-items are created according to three theoretically derived sub-domains: knowledge of students' preconceptions, knowledge of ways of instruction, and knowledge of measuring as well as experimentation. In two pre-pilot studies, experts from universities and expert teachers were asked to evaluate the items with respect to their clearness and relevance (face validity). In the following two pilot studies, the shortened and improved tests were given to teachers of different secondary school types and pre-service teachers. After having finished statistical analyses, the most promising items of both pilot studies were brought together in a final test version which is currently validated in a main study. In the following the reader will be informed about the theoretical background of the project and the process of the test construction. Additionally, first results of the main study will be presented and discussed.

Keywords:

Teacher Professionalism, Competencies, Test Construction, Physics, Secondary School

THEORETICAL FRAMEWORK

Professional knowledge, a sub-domain of teachers' competencies (Bromme 1997) can be conceptually derived from the development of different paradigms such as the expert-novice paradigm. According to it, effective teaching is less a result of characteristics or individual talents of a teacher than of knowledge and competencies which can be learned (Helmke 2007). The professional knowledge of a teacher is said to play a decisive role in effective action in the classroom and for enhanced student outcome (Baumert & Kunter 2006). It is to highlight that professional knowledge is domain-specific, which means that the subject taught serves as a kind of framework for the act of teaching (Baumert & Kunter 2006, Loewenberg Ball, Theule Lubienski & Spangler Mewborn 2001). Furthermore, professional knowledge can be split into three categories: pedagogical content knowledge (PCK), content knowledge (CK) and pedagogical knowledge (PK) (Shulman 1986, Kunter et al. 2011) (figure 1).

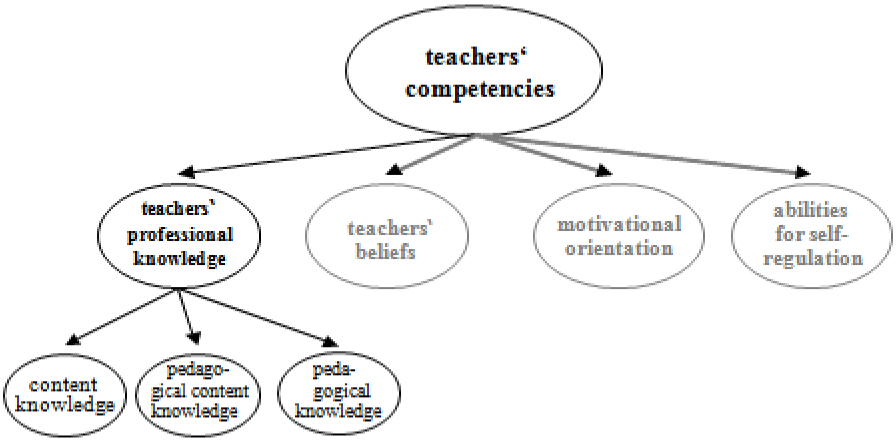

Figure 1. Model of teachers' competencies, according to Bromme (1997).

Within the FALKO project all subjects create tests with items concerning the categories PCK and CK. Additionally there is one test instrument that was developed to measure PK and designed for interdisciplinary use. While existing tests (e. g. Riese & Reinhold 2009) generally consist of CK-items dealing predominantly with mechanics, the FALKO-physics test includes more topics relevant in secondary school (electricity, mechanics, optics, thermodynamics). Moreover, existing tests were developed predominantly for pre-service physics teachers or in-service physics teachers of high-level secondary schools (HLSS), whereas FALKO-physics focuses on in-service-teachers of middle-level (MLSS) and low-level (LLSS) secondary schools. There is one major reason for looking especially on LLSS-teachers for the teaching situation in the LLSS is special. Physics does not exist as a subject itself. Instead, science education takes place within an integrated subject (biology, chemistry and physics). Furthermore, it is common practice that most of the teachers giving science lessons have not studied physics, chemistry, or biology at all.

For that reason the CK-items are created at the level of junior and senior high-school-physics as well as at the level of "enhanced school knowledge". Otherwise the test items would be too difficult to solve for the LLSS-teachers. The level "enhanced school knowledge" is also found in other research projects, for example the MT21-, TEDS-M-, and COACTIV-study or the research project ProfiLe-P.

Concerning the PCK, FALKO-physics distinguishes the two sub-domains "knowledge of students' cognitions" and "knowledge of instruction" similarly to the COACTIV-study. As a further sub-domain, FALKO-physics derived the "knowledge of measuring/experimentation" instead of "knowledge of the potential of tasks". The decision to derive this third sub-domain instead of following the COACTIV-study was on the one hand due to the National Education Standards which clearly states the importance of students' experimentation within the natural science subjects (KMK 2004). On the other hand, experiments play, next to tasks, a decisive role within the students' learning process. Conducting experiments could lead to a conceptual change of students' pre-conceptions towards scientific conceptions (Dollny 2011).
Moreover, experiments offer a wide range of possibilities for a teacher to influence the enhancement of learners' competencies depending on the selection of a suitable experiment, its purpose or its allocation in single steps in order to achieve different educational objectives (Hofstein & Lunetta 2004). Consequently, teachers for the natural science subjects should know about suitable experiments within their lessons. And in addition to that they should choose of suitable experiments, based on the teaching objectives they want to achieve.

The PCK-items of the FALKO-physics test were designed to capture declarative and procedural as well as conditional knowledge (Paris, Lipson & Wixson 1983). Declarative knowledge comprises the knowledge of facts and figures (Anderson et al., 2001). It includes the knowledge that or what something is and also the knowledge of concepts and principles (Paris, Lipson & Wixson, 1983). The procedural knowledge is described as knowledge of actions within the process of teaching and the knowledge of how something occurs (Gruber & Renkl, 2000; Paris, Lipson & Wixson, 1983). The conditional knowledge sums up the knowledge of conditions in which a decision or an action is appropriate. It involves the knowledge which influences the planning and the justification of processes and actions and thus forms the knowledge of when and why a process can be applied or an action can be carried out (Paris, Lipson & Wixson, 1983). Due to the fact that the conditional knowledge is organized situation- and process-oriented (Blömeke et al. 2008), many test items were formulated in order to describe typical situations in class. Moreover, this approach also accounts for the conceptualization of PCK, which was agreed on an international level during the PCK-Summit (PCK-Summit 2012):

"Knowledge of, reasoning behind, and planning for teaching a particular topic in a particular way for a particular purpose to particular students for enhanced student outcomes (reflection on action, explicit).

The act of teaching a particular topic in a particular way for a particular purpose to particular students for enhanced student outcomes (reflection in action, tacit or explicit)."

STATEMENT OF INTENTION

As described above, the FALKO-physics test instrument contains items in relation to the four most relevant topics in the physics curriculum of secondary schools - mechanics, electricity, optics and thermodynamics - within both the PCK- and the CK-items. That is in contrast to other test instruments which have the main focus on mechanics (Riese & Reinhold 2009, Tepner et al. 2012),

In addition, the CK-items are created at the level of junior and senior high-school-physics as well as at the level of "enhanced school knowledge" due to fact that the main focus of our project lies on teachers of MLSS and LLSS and not only on teachers of HLSS and pre-service physics teachers.

Regarding the conceptualization and the development of the test instrument the FALKO-physics project aims to answer, among others, the following research questions with the final version of the test:

- Is it possible to measure the domain-specific professional knowledge (PCK, CK) of physics teachers reliably and validly?
- How do the PCK and CK of physics correlate?
- How do physics teachers at the MLSS and the LLSS differ (PCK, CK)?

METHOD

The whole FALKO-physics pilot study was divided into two separate pilotings (table 1). In pre-pilot study 1, a first version of the test, containing items regarding the topic electricity, was given to six didactics experts (universities) and eight experienced teachers (MLSS, LLSS) in order to evaluate the items (face validity). Here, the experts and expert teachers assessed the items with respect to clearness and relevance on a four-point rating scale (table 2). Some of the participants were videotaped while answering the items (think-aloud, probing).

During pilot study 1, the modified test was applied to a mixed sample of pre- and in-service physics teachers and university staff (N = 75) (figure 2).

Table 1. Overview of the FALKO-physics pilot study.

pre-pilot 1 (experts + expert teachers) **„electricity“** 17 items PCK 36 items CK - face validity + think-aloud/probing - closing + reducing items	**pre-pilot 2** (experts + expert teachers) **„mechanics, optics, thermodynamics“** 13 items PCK 19 items CK - face validity + think-aloud/probing - optimizing code-book
pilot 1 **„electricity“** 14 items PCK (14 open) 19 items CK (11 open) - 6 „instruction“ - 4 „students‘ cognition“ - 4 „measuring and experimenting“	**pilot 2** **„mechanics, optics, thermodynamics“** 13 items PCK (13 open) 19 items CK (5 open) - 4 „instruction“ - 6 „students‘ cognition“ - 3 „measuring and experimenting“

The second pre-pilot study was carried out similarly to the first one (eight didactics experts; four experienced teachers MLSS/LLSS) with another test regarding the topics mechanics, optics and thermodynamics.

Table 2. Table to survey face validity.

Please mark with a cross! **This item / these topics …**	**disagree**	**partially disagree**	**partially agree**	**agree**
… is / are formulated unambiguously.	☐	☐	☐	☐
… contain(s) knowledge relevant for a teacher’s profession.	☐	☐	☐	☐
… should be dealt with during the education of teachers.	☐	☐	☐	☐

Again after that, the modified test was applied to a mixed sample of pre- and in-service physics teachers and university staff (N = 46) (figure 2).

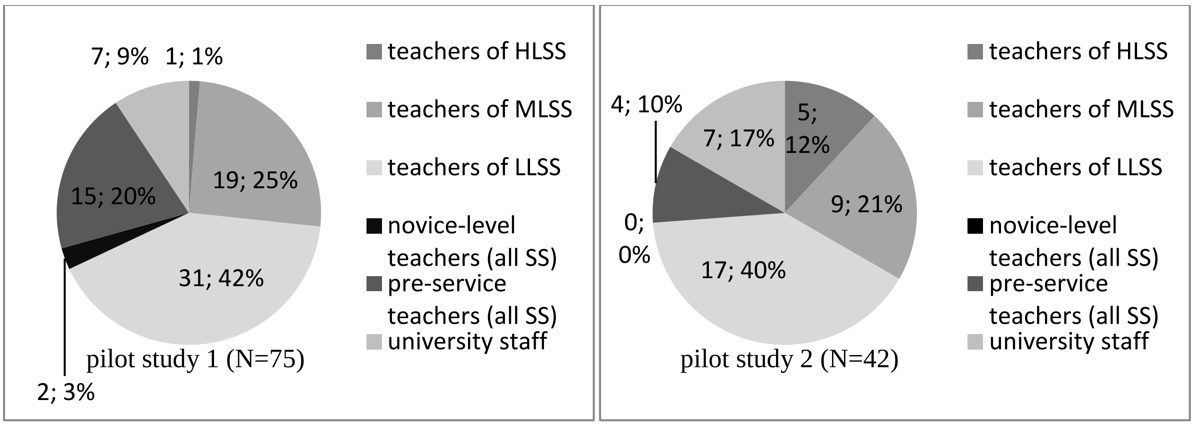

Figure 2. Composition of the samples of pilot study 1 (left side) and pilot study 2 (right side).

The participants of both pilot studies, who ranged in age from 22 to 74 years and in years of teaching experience from zero to 37, answered the items. Moreover, face validity was surveyed using the table from the pre-pilot study 1 (table 2). A codebook to assess the given answers was constructed and two raters were trained to use it.

As already mentioned, FALKO-physics aimed to develop a test instrument dealing with the four topics most relevant in secondary school (electricity, mechanics, optics, thermodynamics). Therefore, selected items of both pilot studies were put together in a final test version (table 3).

Table 3. Overview of the test instrument FALKO-physics, main study.

FALKO-physics: test instrument main study	
PCK:	CK:
topics: electricity (e), mechanics (m), optics (o), thermodynamics (t)	**topics**: electricity, mechanics, optics, thermodynamics
task format: all open-ended	**task format**: mixed forms
items:	**items**:
- 5 „instruction“ (m, e, e, e, e)	- 8 „electricity“
- 5 „cognition“ (m, e, o, t, t)	- 4 „mechanics“
- 4 „meas./exp.“ (e, e, o, t)	- 3 „optics“
	- 3 „thermodynamics“

Criteria for the final choice of the items were:

- results of the face validity (items with the lowest means were removed)
- item difficulty P (.80 ≥ P ≥ .20)
- selectivity (items with negative or low values were removed)
- interrater reliability (items with still low values after having improved the codebook were removed)
- relevance of the four topics in the curricula/standards for secondary schools

The final test version is currently validated in the main study. It has already been given to a mixed sample (N = 237) of pre-service and in-service physics teachers, in-service non-physics teachers and physicists (figure 3). The sample size will be slightly enlarged.

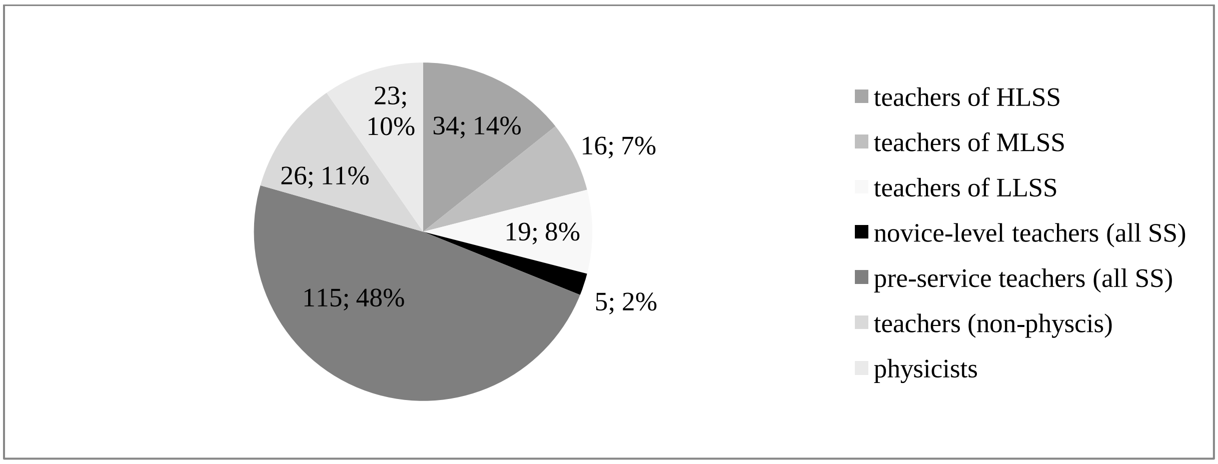

Figure 3. Composition of the main study’s sample.

RESULTS

Regarding the main study, some data has already been analyzed and first results are presented in the following.

Table 4. Item difficulty P (N = 68; all analyzed sub-samples included).

PCK (N = 68)	item min.	item max.	M scale	nr. of items
"instruction"	.80	.43	**.65**	5
"cognition"	.69	.35	**.53**	5
"meas. + exp."	.93	.46	**.63**	4

CK (N = 68)	item min.	item max.	M scale	nr. of items
all items	.75	.28	**.55**	18

When looking at the item difficulties (table 4) one can see that all items have values between .93 and .28. The reliabilities of the item scales (cronbachs alpha) show values of .71 for the PCK items (all open-ended) and 0.85 for CK items (mixed forms) (table 5). By having a more closer look at the theoretically derived PCK sub-scales, one can find values of .54 for the sub-scale "instruction", .51 for the sub-scale "cognition" and .39 for the sub-scale "measuring and experimentation" (table 5). The values for the interrater reliabilities (spearmans rho) lie between .58 and .98 with respect to all open-ended items (table 5). The item selectivity shows values from .182 to .477 for the PCK items and .171 to .668 for the CK items.

Table 5. Reliabilities (N = 68).

(N = 68) PCK	spearmans rho (interr. rel.) min.	max.	cronbachs alpha	nr. of items
„instruction"	.80	.93	.54	5
„cognition"	.84	.96	.51	5
„meas./exp."	.58	.96	.39	4
PCK (all)	**.58**	**.96**	**.71**	**14**
CK (open)	.64	.98	-	12
CK (all)	**.64**	**1.0**	**.85**	**18**

By taking a look at the average test performance one can see values of 39 % (SD = 17 %) for the whole sample regarding all items, of 34 % (SD = 15 %) for the whole sample regarding the PCK items and 43 % (SD = 23 %) regarding the CK items (figure 4). The calculated values for the sub-samples can be found in figure 4. The correlation between the PCK- and the CK-scale is .71 (two-sided, p < .01, N = 93).

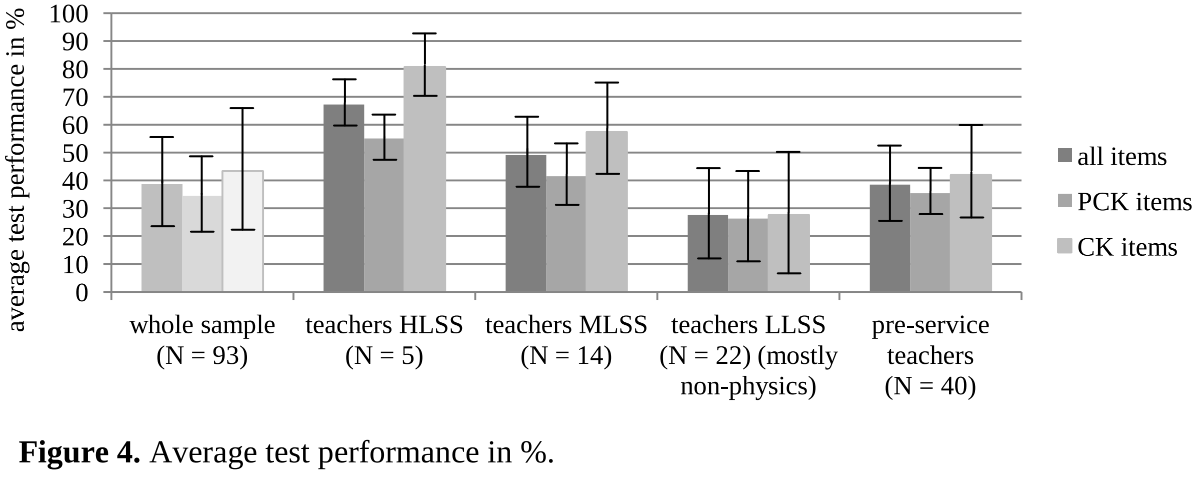

Figure 4. Average test performance in %.

DISCUSSION AND CONCLUSIONS

It should be noted, that not the whole sample has been analyzed yet. For that reason, the following statements are to be treated with caution.

By taking a look at the item difficulties, one can see that the numbers are located, except for one item of the PCK-scale, between the requested values of P = .80 and P = .20 (Bühner 2011). The item with the slightly too high difficulty due to a modification of the codebook should be removed from the test. This would also have a positive effect on the processing time which is currently around 90 minutes. The items' selectivity has acceptable values. Those few items whose values are slightly too low can be justified on the content level (face validity).

The scale reliabilities are considered to be good for the PCK scale, especially when mentioning the fact that all PCK items are open-ended, and quite good for the CK scale. Regarding the PCK sub-scales, one could argue that the reliabilities are just about to be satisfactory (sub-scale "instruction" and sub-scale "cognition") or even not satisfactory (sub-scale "measuring and experimentation") (table 5). But it is to highlight, that those three theoretically derived sub-scales served only as a basis for constructing items with different content.

The interrater reliability for both the PCK-items and CK-items are considered to be in between satisfactory and good. Only two items have values that are not acceptable yet. One possibility to improve the values would be a modification of the code book. If this would not be that effective, another way could be to remove those two items from the test. This would not have a huge impact on the scale reliabilities (already calculated) but also a positive effect on the processing time of the test.

When looking at the test performances, neither ceiling nor bottom effects are expected when applying the test in a field study. As expected, the physics teachers of HLSS, who studied physics on the most intense level, show the best test performance, followed by the teachers of MLSS and LLSS whose courses at university are of less depth. As a fact, it is to stress that all HLSS and MLSS teachers studied physics at university, whereas only four of our LLSS teacher sample did so. All the others teach physics without ever having studied physics as a main or a minor subject, as already described in the theoretical framework of this paper. For this reason, it is not even surprising that the average test performance of the pre-service teachers is higher than the one of the LLSS teachers.

The correlation (manifest value) between the PCK- and the CK-scale is satisfactory. However, a latent modelling has to be done as soon as enough tests are analyzed in order to look how appropriate our theoretically derived model will fit the data.

A next step is, besides further statistical analyses especially concerning the sub-samples, to validate the test instrument by applying it to contrast populations (e. g. biology/chemistry/math teachers, physicists). As another possibility, the test performance could be correlated with student outcomes (knowledge test). Furthermore, it could be correlated with factors that describe effective teaching (teacher observation).

REFERENCES

Anderson, L. M.; Krathwohl, D. R.; Airasian, P. W.; Cruikshank, K. A.; Mayer, R. E.; Pintrich, P. R. (2001): A Taxonomy for Learning, Teaching and Assessing: A Revision of Bloom's Taxonomy of Educational Objectives. *P. R. Pintrich (Ed.): A Taxonomy for Learning, Teaching and Assessing: A Revision of Bloom's Taxonomy of Educational Objectives.* New York: Longman.

Baumert, J., & Kunter, M. (2006). Stichwort: Professionelle Kompetenz von Lehrkräften. *Zeitschrift für Erziehungswissenschaft, 9*(4), 469–520.

Blömeke, S., Kaiser, G., & Lehmann, R. (Eds.) (2008). *Professionelle Kompetenz angehender Lehrerinnen und Lehrer. Wissen, Überzeugungen und Lerngelegenheiten deutscher Mathematikstudierender und -referendare. Erste Ergebnisse zur Wirksamkeit der Lehrerausbildung*. Münster: Waxmann.

Bromme, R. (1997). Kompetenzen, Funktionen und unterrichtliches Handeln des Lehrers. In F. E. Weinert (Edts.), *Psychologie des Unterrichtens und der Schule. Pädagogische Psychologie (Enzyklopädie der Psychologie)* (pp. 177–212), Göttingen: Hogrefe.

Bühner, M. (2011). *Einführung in die Test- und Fragebogenkonstruktion.* Hallbergmoos: Pearson Deutschland.

Dollny, S. (2011): Entwicklung und Evaluation eines Testinstruments zur Erfassung des fachspezifischen Professionswissens von Chemielehrkräften. *H. Niedderer, H. Fischler und Sumfleth E. (Hg.): Studien zum Physik- und Chemielernen, 127,* Berlin: Logos.

Gruber, H.; Renkl, A. (2000): Die Kluft zwischen Wissen und Handeln: Das Problem des trägen Wissens. G. H. Neuweg (Ed.): *Wissen - Können - Reflexion. Ausgewählte Verhältnisbestimmungen* (pp. 155–174). Innsbruck: Studienverlag.

Helmke, A. (2007). *Unterrichtsqualität - erfassen, bewerten, verbessern.* Seelze: Friedrich.

Hofstein, A.; Lunetta V. N. (2004): The Laboratory in Science Education: Foundations for the Twenty-First Century. *Science Education, 88,* 28–54.

KMK (2004). *Bildungsstandards im Fach Physik für den mittleren Schulabschluss,* access on http://www.kmk.org/fileadmin/veroeffentlichungen_beschluesse/2004/2004_12_16-Bildungsstandards-Physik-Mittleren-SA.pdf

Kunter, M., Baumert, J., Blum, W., Klusmann, U., Krauss, S., & Neubrand, M. (Eds.) (2011). *Professionelle Kompetenz von Lehrkräften. Ergebnisse des Forschungsprogramms COACTIV.* Münster: Waxmann.

Loewenberg Ball, D., Theule Lubienski, S., & Sprangler Mewborn, D. (2001). Research in Teaching Mathematics: The Unsolved Problem of Teachers' Mathematical Knowledge. In V. Richardson (Ed.), *Handbook of research on teaching* (pp. 433–456). New York: Macmillan.

Paris, S. G., Lipson, M. Y., & Wixson, K. K. (1983). Becoming a Strategic Reader. *Contemporary Educational Psychology, 8,* 293–316.

PCK-Summit 2012, http://pcksummit.bscs.org

Riese, J., & Reinhold, P. (2009). Fachbezogene Kompetenzmessung und Kompetenzentwicklung bei Lehramtsstudierenden der Physik im Vergleich verschiedener Studiengänge. *Lehrerbildung auf dem Prüfstand, 2 (1),* 104–125.

Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher, 15(2),* 4–14.

Tepner, O., Borowski, A., Fischer, H. E., Jüttner, M., Kirschner, S., Leutner, D., Neuhaus, B., Sandmann, A., Sumfleth, E., Thillmann, H., Wirth, J. & Witner, S. (2012). Modell zur Entwicklung von Testitems zur Erfassung des Professionswissens von Lehrkräften in den Naturwissenschaften. *Zeitschrift für Didaktik der Naturwissenschaften, 18,* 7–28.

PRE-SERVICE TEACHERS' PERCEPTIONS ABOUT MODELLING: FIRST STEPS TOWARDS A REFLECTIVE PARTICIPATION IN SCIENTIFIC PRACTICES

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Abstract: From a view of science learning as participation in the practices of science, we understand that the scientific contents are knowledge inseparable from scientific activity (Michaels, Shouse, & Schweingruber, 2008). However, science is not taught as a practice in which to participate, but as a propositional knowledge to be learnt. To achieve a significant change in school teaching practices, we should start with initial teacher education. However, it has been recognized by the literature that this new framework poses great challenges to pre-service teachers.

This study aims to give insights in this area, analysing pre-service primary school teachers' perception of scientific practices within a teacher education course based on models and modelling. More specifically we want to identify pre-service teachers' perceptions about the effectiveness of participating in modelling activities for both their learning of science and their future teaching practice. For doing so, we designed and implemented a semi-open questionnaire with 80 pre-service teachers. The questionnaire asked for pre-service teachers to choose and justify their choice regarding the teaching activities of the course that had a higher impact in their learning. The analysis differentiate between those activities of the course that were typical of model-based instruction from other teaching and learning activities.

Results show that most pre-service teachers recognized modelling activities (use, express, evaluate and revise models) as crucial for their learning of the scientific models, highlighting revision processes and model-based inquiry approaches as especially useful. Others considered that other type of activities (such as hands-on practical work or teacher's clarification of ideas after a task) were also important for their learning.

Keywords: Scientific practices, pre-service teachers, modelling, reflective practice

INTRODUCTION

Why scientific practices in primary school initial education?

The standpoint is a view of science education as the engagement in scientific practices (NRC, 2007), moving from an interest in the products to an interest in the processes and practices of science (Duschl & Grandy, 2008). Justified in terms of learning potential and epistemic adequacy (Bybee, 2011), the scientific practices framework proposes an underlying structure for scientific activity based on the interrelated core practices of modeling, inquiry and argumentation (Osborne, 2014).

In general, science is not taught as a practice in which to participate, but as a propositional knowledge to be learnt (Duschl & Grandy, 2008). "Often in science class, students are given the final, canonical scientific model that scientists have developed over numerous years, and little time is spent showing them the evidence for the model or allowing them to construct models that will explain phenomena." (Krajcik & Merritt, 2012, p. 39). As a consequence, scientific concepts are not understood as knowledge inseparable from scientific activity (Bybee, 2011; Izquierdo, 2005).

From the viewpoint of science as a social practice, "its learning entails apprenticeship into a legacy of conceptual knowledge and epistemic practices" (Kelly, 2013, p. 1), by socializing in the practice of a school science or school scientific activity: to think, do and speak science. (Izquierdo, 2005; NRC, 2007). As Michaels and colleagues (2008, p. 34) explain, "when students engage in scientific practice they are embedded in a social framework, they use the discourse of science, and they work with scientific representations and tools [...] This perspective is a far better characterization of what constitutes science and effective science instruction than the common tendency to teach content and process separately."

Engaging students in this type of science learning is necessarily a matter of teacher education that should start in initial training. It is important to start with elementary teachers, who "play a critical role in early science learning – establishing the foundation for learners that can enable or constrain them from learning to participate and appropriate scientific practices" (Schwarz, 2009, p. 2). Nevertheless, their initial training has been recognised as problematic (Osborne & Dillon, 2008) and this new framework poses specific great challenges for pre-service teachers (NRC, 2012; Reiser, 2013) that demand for well-designed teacher education courses that give support with the practices as well as the scientific ideas addressed by those practices (NRC, 2007).

A good way to overcome these challenges is to make pre-service teachers experience first-hand (as students) the type of learning activities that they will later have to provide to their students (Davis, 2003). Actually, teachers (as well as students) cannot comprehend science practices, nor fully appreciate the nature of scientific knowledge itself, without directly experiencing those practices for themselves (Crawford, 2014), which highlights the need of engaging pre-service teachers, actively and meaningfully in school scientific practices.

Another important aspect in teacher preparation is the participation in a reflective practice. Some authors have highlighted the importance of explicit reflection to improve transference to teachers (Iordanou & Constantinou, 2014), as for example reflection about the how and the why of those practices (Berland et al., 2015; Osborne, 2014), or the appreciation of the importance of modelling as a crucial scientific practice (NRC, 2012).

In this research we investigate which perception Pre-Service primary school Teachers (PSTs) have about modelling as a useful practice to learn the scientific models, after having participated in a teacher education course based on models and modelling, aiming to do some first steps towards a reflective participation in the scientific practices.

Our vision of model-based instruction and models

Taking Osborne's (2014) vision of scientific activity, we focus on the modelling practices, understanding modelling as both social and personal engagement in "*sensemaking around developing ideas*" (Schwarz et al., 2009, p. 637), rather than the common approach to models as communication of finalized ideas. As such, school modelling encompasses the practices of co- and self- construction and evaluation of models, which take place when engaging in the expression, use, evaluation and revision of models. In agreement with and elaborating from Schwarz and colleagues, we made an attempt to operationalize the modelling practice that can be made accessible and meaningful at school, defining and developing 6 phases for the construction of the model (which are the teaching aim of an adequate instructional sequence on modelling):

M1. Feel the need of a model (to explain or act upon a phenomena)
M2. Express / use an initial model (think individually)
M3. Evaluate the model (analyse the level of adjustment with reality / testing the model)

M4. Review the model (sophisticate and improve inadequate specific aspects of the model with the help of other's ideas)
M5. Express a final consensus model
M6. Use the model to predict or explain new phenomena

In addition, our view of modeling stands from the assumption that participation in school scientific practices is not only for learning to engage in these practices (procedural dimension) or about these practices (epistemic dimension), but also for learning scientific models (conceptual dimension) in which to frame them. From our viewpoint, the models to be constructed, evaluated etc. in the classroom are those related with the *big ideas* of science: a small number of key scientific ideas (Harlen, 2010) or core ideas (NRC, 2012) that have potential to explain a lot of different phenomena in the natural world, such as the particle model of matter.

Objective and research questions

In this proposal we focus on investigating the perceptions of PSTs about their engagement in modelling practices during the teaching education course, in relation to their learning of science and to their future teaching practice.

1. Which value do Pre-service Teachers (PSTs) give to modelling as a useful practice to learn scientific models?
2. To what extend do PSTs identify that the teaching approach used in the course is model-based?
3. How do PSTs position themselves as future teachers regarding the inclusion of modelling in their teaching?
4. What problems do PSTs identify in the course?

METHODS

Context

Our investigation takes place in the context of a compulsory 3rd year-course on science teaching within the four year elementary teacher degree, which has been collaboratively designed by a group of science education researchers and based on literature about primary-school teachers training (Mikeska, Anderson, & Schwarz, 2009). The subject aims to engage PSTs in modelling practices focusing on inquiry and group discussions, to construct the main school scientific models (geology, physics, chemistry and biology). This is done by anchoring phenomena and asking PSTs to elaborate hypothesis and mental representations to use and express their initial model, to search for new evidence to evaluate the model, to discuss with peers to revise the model, to build a consensus model or apply the model to new situations, etc. The subject had 12 weekly sessions between lectures and seminars, and took place from Sept-15th 2014 to Dec-8th 2014.

Research methods

We designed and piloted a semi-open questionnaire that was completed by 80 PSTs on the last day of the course. We analysed the questionnaires that were fully answered (N= 77).

In the first part of the questionnaire PSTs were asked to select, from 14 activities that were done throughout the course, the 5 activities that helped them the most to learn the scientific models. In the next question they had to explain why. Some activities were categorised as modelling practices (*Modelling*), and some were considered other type of activities (*No Modelling*). The activities were ordered randomly (modelling and no modelling) within the questionnaire. After the implementation of the questionnaire and the analysis of the reasons given by PSTs, 2 of the *No modelling* activities were discarded (not used in the analysis) because they were drafted too general/imprecise and therefore they could be understood in a way that included modelling processes. The rest of the activities were considered for analysis: 7 *Modelling* and 5 *No modelling* activities. Table 1 shows the 12 activities (with examples), as written in the questionnaire (left and middle columns). On the right column, we indicate the category give to each activity (information not included in the questionnaire): the phase of the modelling practice (in the case of *Modelling* activities) or the type of task (in the case of *No modelling* activities).

Included in the questionnaire		**NOT included in the q.**
Activity	**Example of activity**	**Phase of the modelling practice / type of task**
1. Elaborate hypothesis before doing an experiment or draw how I initially imagine a process	*Answer to question: "how do you think mass will change? Why?"* *Draw the cycle model, the way an apple makes through the body and how may look the salt dissolved in water.*	M.2. Use and express the initial model (individually)
2. Use analogical models	*Doing the geological cycle with play dough, the scale model about nutrition or using plastic pieces to represent a chemical reaction.*	M.6. Use the model (or analogical model) to predict/explain phenom.
3. Explain phenomena or evidence obtained from an experiment.	*Answer to question: "how can the cave being formed?"*	M.6. Use the model (or analogical model) to predict/explain phenom.
4. After doing an experiment, having to re-think my initial explanation because data doesn't fit with it.	*Re-think my explanation about how is the change in state of matter, after seeing that water can boil at 70ºC.*	M.3. Evaluate the model
5. Doing Auto-evaluation and Co-evaluation	*Co-evaluate others' drawings of the water cycle or the experiments designed by peers regarding the particle-model of matter.*	M.3. Evaluate the model M.4. Review the model
6. Seeing real examples of students' responses and answers	*Children's drawings of the different changes of a river stone.*	M.4. Review the model
7. Re-think the explanation that I gave to phenomena after listening to a new idea from peers or new information given	*When the teacher said that the speed of an object in free fall doesn't depend on the mass of the object.*	M.4. Review the model M.5. Express or build a consensus final model
8. Carry out an experiment using different instruments	*Boiling water in a vacuum container, use test tubes or lab pins, look at sparkling pills…*	Do hands-on tasks
9. Start a new topic by listening to the key ideas of the model from the teacher	*Listening to ideas about geological change, chemical change, mechanical interaction, nutrition function, etc.*	Listen to finalised ideas before the lesson
10. Learning scientific words, scientific culture and curriculum contents.	*Learning words such as "oxidation, weathering", or the Archimedes' principle.*	Learn scientific terms, laws or curricular contents
11. Receiving the corrected answers from the teacher after doing a task.	*The lecture classes after the seminars*	Listen to the "correct" scientific ideas after a task
12. Reading literature or papers related to the model that we are working on.	*The paper: "Teaching the water cycle from the perspective of explicative models."*	Receive theoretical information disconnected from the modelling practice

Table 1: Activities and examples included in the questionnaire, and phase of the modelling practice or the type of task that each activity implies (not given to PSTs).

In a second part of the questionnaire, we presented three primary-school teaching proposals with different teaching aims/approaches: Inquiry (proposal 1), Modelling (proposal 2) and Contextualization/environmental awareness (proposal 3). All three proposals were interesting, innovative and high-quality teaching approaches, as well as common orientations in our local context (teacher training, primary schools, etc.) (see Table 2). After reading the three proposals, PSTs were asked to: 1) select which proposal was more similar to the activities done in the subject, and 2) choose which proposal they would teach if they were teachers.

Proposal 1 (Teaching aim/approach: **Inquiry**)
Let's design the best filter to clean water! *Children are asked to take a bottle with water and introduce different things to make it dirty. They are asked, "how could we the best clean the water?" and they are asked to think about a possible experimental design to filter the water. In small groups, they think of different strategies, perform their experimental design and take note of the results for each filter. Each group presents its filter to the rest of the class, describing which substances have gone through and which ones not. In the end, they have to vote for the best filter, and the best one is chosen.*
Proposal 2 (Teaching aim/approach: **Modelling**)
Why does it go through the filter and why not? *In small groups, students are given two bottles: one with clean water and the other with dirty water. Students are asked to draw the content of each bottle and how they imagine a drop from the inside. Students are given two types of filters (metal grille frame and filter paper) and they are asked what they think will happen in each case. Students make hypotheses, then they filter the dirty water with each filter and they take note of the results. Then, they are asked: "Why do some substances pass through the metallic grid and some other no? And through the filter paper?" In small groups, they discuss and write their explanations.*
Proposal 3 (Teaching aim/approach: **Contextualization/environmental awareness**)
Which one pollutes the most? *The teacher explains that to clean dirty water they can be used different filters, but these do not always separate all the substances that are in the water because some substances pass through the holes of the filter. In groups, students are asked to make a list of the things they normally throw down the drain and the ones they think could be removed with a filter. They search on the internet about which substances are regularly cleaned in treatment plants and watch if their ideas match with the information found. In the end, students go into their neighbourhood and talk to people explaining them that they should not throw things into the sink to avoid polluting the environment.*

Table 2: Primary-school teaching proposals included in the questionnaire.

Analysis

In order to know the value PSTs gave to modelling (RQ1) we first analysed the relative importance that PSTs gave to each type of the activities done in the subject (*Modelling* or *No modelling*) by calculating the percentage of PSTs that selected each activity from the list included in the questionnaire, and by comparing the *Modelling* and *No modelling* activities. Secondly, we investigated the reasons, by doing a bottom-up analysis of their open responses, identifying which ideas appeared in their argumentations regarding each type of activity, grouping the type of reflections and building up representative categories and finally selecting representative quotes of each. The same type of analysis was done to know the problems PSTs identify within the subject (RQ4), using the qualitative analysis software *Atlas.ti*.

To know if PSTs identified the teaching approach used in the course (RQ2) and how they position themselves as future teachers regarding the use of modelling practices in their classes (RQ3), we did quantitative analysis, calculating the percentage of PSTs that identified each teaching proposal and the percentage that selected each proposal as a possible option for teaching science in the future.

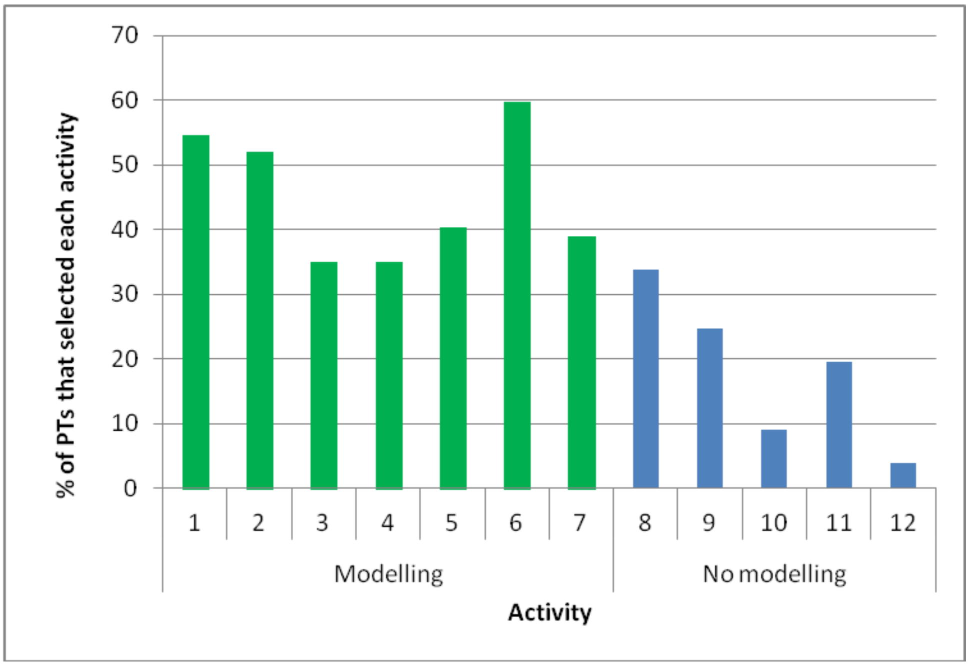
3. RESULTS

3.1. Value that PSTs give to modelling for learning science

Regarding the relative importance that PSTs gave to each type of the activities done in the course (*Modelling* or *No modelling*), all modelling activities were selected by more PSTs than the other No modelling activities, as shown in Graph 1. On average, each modelling activity was selected by 45% of PSTs, while each No modelling activity was selected by 18% of them, clearly showing that modelling activities were found by PSTs more useful to learn science than other type of activities.

Regarding modelling activities, activities 1 (*Use and express the initial model*), 2 (*Use the model to predict or explain phenomena*) and 6 (*Review the model*) were chosen by more than half of PSTs (50-60%). That is, processes of using/expressing initial models and having explicit theoretical information to review their ideas were highly valued by PSTs. The rest of Modelling activities – 3 (*Use the model*), 4 (*Evaluate the model*), 5 (*Evaluate and Review the model*) and 7 (*Review the model and express or build a consensus final model*) – were selected at least by one third of PSTs (35-45%). These are processes of using the model to explain new phenomena or evaluating/reviewing it after having more evidence or more information from peers or the teacher.

No modelling activities, on the contrary, were selected by less than one third of PSTs: activity 8 (*Do hands-on tasks*) was chosen by 34% of PSTs, activity 9 (*Listen to finalised ideas before the lesson*) and 11 (*Listen to the "correct" scientific ideas after a task*) are around 20%, and activity 10 (*Learn scientific terms, laws or curricular contents*) and 12 (*Receive theoretical information disconnected from the modelling practice*) were the less voted (<10%) and therefore, the less valued by PSTs as useful to learn science.



Graph 1: Number of PSTs selecting each activity (7 *Modelling* and 5 *No modelling)* included in the questionnaire and done during the course. In green (1-7), "Modelling" activities. In blue (8-12), "No Modelling" activities.

Qualitative results show the reasons given by PSTs when choosing each type of activities (both when referring to modelling and to other type of activities). The different ideas that arose in their answers are described below.

3.1.1. Reasons for choosing Modelling activities

We identified four common ideas or perceptions about the reasons to choose *Modelling* activities:

- Idea 1: The usefulness of the model-based instructional phases, which are cognitive-discursive phases (think, experiment, discuss, re-think), for learning

> The main reason given by PSTs selecting modelling activities from the list is that engaging in these scientific modelling practices (i.e. in the expression, use, evaluation and revision of their mental model) in a certain way (by following a specific modelling sequence such as trying to explain phenomena, formulate initial hypothesis, doing experiments to find new evidence, discuss with peers, re-think their explanation, etc.) helps them achieve a meaningful construction of the key scientific models.
>
> > *A18: "Thinking an explanation, doing the experiment, re-thinking the explanation because results don't match with it, etc. are necessary processes to understand better what we are learning."*
> >
> > *A27: "Thinking before doing anything, which is challenging but useful, with the experiments and most of all, doing evaluation activities or re-formulating my own ideas is what has helped me the most."*

- Idea 2: The importance of having access and discuss other versions of the model in the revision phase

Some PSTs focused on the revision processes, highlighting peer-discussion and re-thinking explanations in the light of new evidence as good ways of changing previous ideas and achieving significant learning.

> *A10: "I think that interacting and correcting mistaken ideas is the best way that I can learn."*
>
> *A15: "Discussing and learning from peers' ideas helped me understand it better."*
>
> *B8: "Doing analogical models, trying to explain phenomena or re-think my own explanation after listening to another person's ideas are the activities that have helped me the most in building the scientific model."*

PSTs also realised that indirect ways of revising the model, such as knowing common pupils' ideas about the model, helped them feel more confident with their own doubts.

> *C13: "It is important to see some examples of pupils' doubts, it helps me feel less shy to ask my own doubts."*

- Idea 3: The limitations of naive views of inquiry versus model-based inquiry

Some PSTs focused on the type of inquiry practices promoted in the classroom, mostly focused on minds-on processes for the construction of the target model. They highlighted the importance of doing a type of inquiry that includes model building (i.e. using the model to think of explanations of the results), instead of mere experimentation or hands-on laboratory tasks without reflection or connection with the model.

> *A1: "I have chosen these activities because those are the ones that have helped me reflect and think; and finally construct these scientific models. 3 of them are related to experimentation, which is interesting to see things, but they should be accompanied of reflection. If not, they are useless."*
>
> *A24: "Discovering the "why" of things [explanation of phenomena] is what makes me learn."*

C9: "Learning science is not just knowing scientific concepts or doing experiments. I think we also learn science by thinking (hypothesis, explanations, etc.) and we learn with our peers (we see our own mistakes, new ideas, etc.)"

- Idea 4: the role of modelling as a facilitator of meta-cognition

Others have also mentioned the importance of modelling for meta-cognition, such as for being aware of their own learning process, their challenges and their capability to do science.

A2: "Trying to think on my initial ideas makes me later realize about what I have learnt and what I didn't know at the beginning."

A5: "Auto-evaluation and co-evaluation are also essential to analyze my task from another perspective and be aware of my own mistakes."

B11: "These activities (doing analogical models, trying to explain phenomena and re-thinking explanations with new evidence) have helped me question my previous ideas and realize that we [PSTs] can also think and construct science."

3.1.2. Reasons for choosing other (no modelling) activities

Pre-service teachers that chose *No modelling* activities gave other reasons for their choices.

- Idea 1: The view of "learning by doing" and other motivational aspects

Many PSTs gave emphasis to practical work, considering it useful to achieve concept understanding, because it motivates them to learning, it is a new way of looking at things, or just because they learn when they "do" in an experimental way.

A13: "The practical tasks have helped me understand concepts better."

A29: "I think that we learn by doing."

C13: "Practical work always gives us a new and innovative way of looking at things."

B3: "Manipulating different materials I learn more because the learning process is more dynamic and therefore it motivates me more."

- Idea 2: The importance of the final ("correct") scientific ideas vs importance of the process of developing these ideas

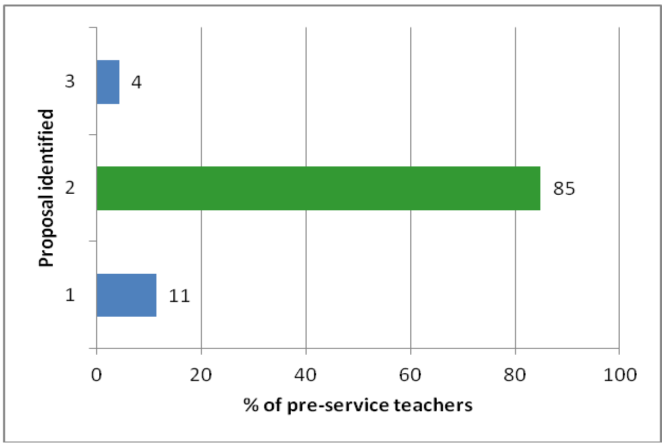
PSTs also valued teacher's final lectures and explanations after a task to clarify their remaining doubts.

A20: "Sometimes I didn't have the main ideas clear and the feedback of the teacher really clarified my ideas."

C13: "Teachers' explanation of concepts after a task is necessary to solve any possible doubts."

3.2. Identification of the teaching approach of the course

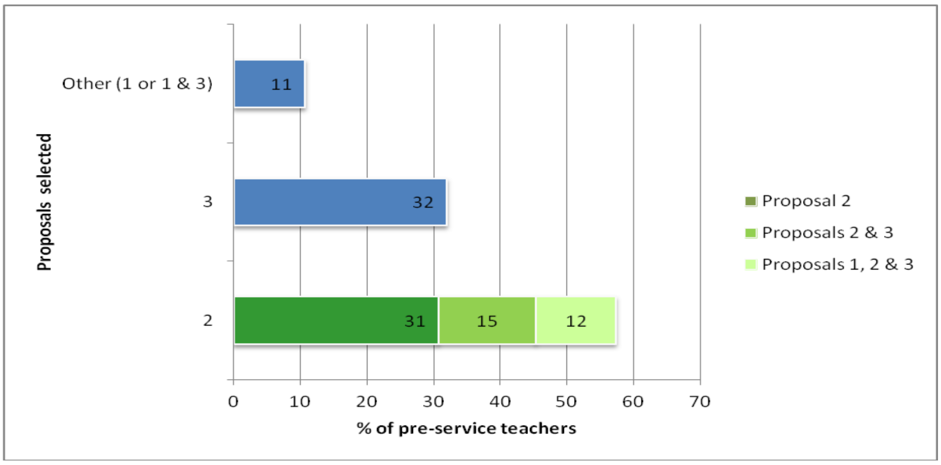
Regarding the identification of the teaching approach used during the course (RQ3), most pre-service teachers (85%) were able to identify the proposal reflecting a model-based instructional approach (teaching proposal 2) as the most similar to the one used in the course (see Graph 3). Only 11% of PSTs selected proposal #1 (reflecting an inquiry-based pedagogical approach) and 4% chose proposal #3 (reflecting a context-based approach).



Graph 3: % of PSTs that identified each of the three proposals given.
(#1 inquiry, #2 modelling, #3 contextualization/environmental awareness)

3.3. PSTs' position as future teachers

Regarding the type of teaching proposal that they would choose for teaching in the future (a model-based, inquiry-based or context-based approach), proposal #2 (model-based) was well valued in compared to the others. Most PSTs would teach activities such as proposal #2, whether combined with proposal #3 (15% of PSTs), with proposals #1 and #3 together (12%), or just by itself (31%) (see Graph 4, green bar). 32% of PSTs chose proposal #3 by itself (context-based approach), and 11% of them chose other combinations, whether proposal #1 (inquiry-based approach) or #1 and 3# together.



Graph 4: % of PSTs that selected each of the three proposals (or combined) as the type of activities that they would choose for teaching in the future.
(#1 inquiry, #2 modelling, #3 contextualization/environmental awareness)

3.4. Problems with the teacher education course

When asking PSTs about what was problematic about the course (RQ2), different shortfalls were noted. Many of them mentioned the lack of time as one of the most important weaknesses, affecting their actual learning because they didn't have enough time to interiorise the new ideas or concepts related to the models.

> *A1: "I have missed having more time. Science is difficult for me and I didn't have enough time to do a significant learning."*

> *A25: "I think there was too many activities in the seminars and not enough time to do them well and understand them well."*

Some of them even suggested possible changes, such as including fewer models in the course and studying them more in depth, or keeping all scientific contents (which they consider very interesting) but having more time to work on them.

> *A6: "May be I wouldn't have included so many topics and I would have deepen in some. The lack of time has been one of the aspects when doing tasks."*

> *B20: "We lacked more time. In 3 months we had to do many activities, tasks and learning many concepts, very interesting, but without enough time."*

Pre-service teachers realized of other problems in the subject. For example, some of them commented that they needed more feedback, deeper explanations and more clear evaluations from the teacher after each session, to clarify the key ideas of the models and to achieve meaningful learning. This is closely related to idea 2 from the reasons to choose No modelling activities from the list.

> *C8: "It lacked a more detailed explanation of what we had done right or wrong, in order to have a clearer idea and be able to improve and learn."*

> *C16: "Doing a reflection after each content about what we have learnt, relevant aspects, etc. would have been good to finally achieve the knowledge construction."*

> *C19: "I needed a little bit more theory and explanations. I think we have gone through some aspects very superficially."*

4. DISCUSSION AND CONCLUSIONS

Regarding the first research question about the value that PSTs give to modelling as useful to construct the scientific models, modelling activities were more valued than no modelling activities. On average, modelling activities were selected by 45% of PSTs, while no modelling activities by 18% of them. Among all modelling activities, those that required the use of the model to explain new phenomena or the evaluation or revision of the model after having more evidence or new theoretical information (from peers or the teacher), were the most valued ones by PSTs.

Regarding the reasons given to choose modelling activities, many were focused on the modelling sequence (following specific steps: express the initial model, test de model, engage in discussion, re-think the model, build a consensus model, etc.), highlighting the importance of following this type of sequence to achieve a meaningful learning. They also expressed that revision processes, such as auto-evaluation or co-evaluation of activities, are key stones for learning. PSTs were very critical with practical work, highlighting the importance of building explanations based on the model in contrast with just participating in hands-on experiments, clearly valuing model-based inquiry approaches. Actually, they critically reflected on the different teaching approaches, mentioning that engaging in modelling is better for learning science than other approaches, such as just learning finalised ideas or participating in practical work. PSTs also considered that modelling practices fostered meta-cognition, because by engaging in the processes of expression, evaluation, etc. of models, they became aware of their learning process and their own capabilities to engage in science.

Those who chose no modelling activities as important for learning gave other reasons, such as the positive aspects of practical work (motivation, etc.). It should be taken into account that all practical work within the subject was focused on minds-on processes for the construction of the target model. Therefore, although these PSTs clearly highlighted the "hands-on" part of the activity, it is difficult to know if they had a naïf view of the scientific activity (as just hands-on inquiry), or they didn't differentiate between lab work and modelling practices because the lab work was mainly focused on building models. It would be good for future situations to make the NOS more evident throughout the course, making explicit reflections about it, such as if we learn directly from the experiment or not, etc. Finally, PSTs also pointed out the need of teacher's clarification of ideas and concepts after a modelling practice, to clarify any possible doubts still remaining after a session. Although modelling is important by itself, PSTs also need, at some point, the expert's view. In their opinions, they asked for feedback, or a "recapitulacion" of the key ideas of the reconstructed version of the model that we want them to learn (target model), and therefore, this phase should be included in the instructional sequence when planning a modelling practice.

Regarding other problems or shortfalls they found in the course, they were aware of the high demand this type of activities implies, in terms of time, to deeply work and construct each idea of the model. They asked for more time to interiorize ideas, suggesting to reduce the content included in the course and to dedicate more time to each idea, in order to achieve deep cognitive work, satisfying modelling practices and clear final ideas of the target models to be constructed.

Most PSTs clearly identified the teaching strategy used in the course (modelling approach), by choosing the teaching proposal most similar to the course, although the other two teaching proposals offered were very attractive and commonly used in our context. These results show that, in spite of all the problems faced during the course (lack of time, too many models, activities not focused on modelling, lack of clarification on some ideas of the models…), PSTs were able to recognise the modelling teaching approach used, which clearly differs from an inquiry approach or a context-based/environmental approach.

When positioning themselves as future teachers, most PSTs included modelling in their teaching approach, whether combined or not with other teaching approaches (context-based/values approach in most cases, but also inquiry), which shows that they value modelling as a good approach for their teaching practice at primary school level, but including other important aspects. The context-based/values approach was also chosen by many PSTs, demonstrating that future teachers also value contextualization of scientific contents when thinking of teaching science in primary school. This is probably due to a competence-based tendency in our context, but also reminds us that it is important to use and build scientific models in real, close and significant contexts for children, as well as to include values and awareness in our science classes. In this sense, scientific practices give us a roadway of what to do in the classroom, whether scientific competence shows us the objective: to achieve scientific literacy. Next step would be to integrate scientific practices to build key scientific models in a broader and "with-values" context, to actually become fully and scientifically competent.

5. REFERENCES

Berland, L. K., Schwarz, C. V, Krist, C., Kenyon, L., Lo, A. S., & Reiser, B. J. (2015). Epistemologies in Practice : Making Scientific Practices Meaningful for Students. *Journal of Research in Science Teaching*, (In press).

Bybee, R. W. (2011). Scientific and Engineering Practices in K-12 Classrooms: Understanding "A Framework for K-12 Science Education." *Science Teacher*, *78*(1), 34–40.

Crawford, B. A. (2014). From inquiry to scientific practices in the science classroom. In S. Lederman, N. & Abell (Ed.), *Handbook of Research on Science Education. Vol II*. New York: Rutledge.

Davis, K. S. (2003). "Change is hard": What science teachers are telling us about reform and teacher learning of innovative practices. *Science Education*, *87*(1), 3–30.

Duschl, R. A., & Grandy, R. E. (2008). *Teaching Scientific Inquiry: Recommendations for Research and Implementation*. Rotterdam, Netherlands: Sense Publishers.

Harlen, W. (2010). *Principles and big ideas of science education* (p. 60). Gosport, Hants, UK.

Iordanou, K., & Constantinou, C. P. (2014). Developing pre-service teachers ’ evidence-based argumentation skills on socio-scienti fi c issues. *Learning and Instruction, 34*, 42–57.

Izquierdo, M. (2005). Hacia una teoría de los contenidos escolares. *Enseñanza de Las Ciencias*, *23*(1), 111–122.

Kelly, G. J. (2013). Inquiry teaching and learning: Philosophical considerations. In Michael R. Matthews (Ed.), *Handbook of Historical and Philosophical Studies in Science Education*. Pennsylvania State University: Springer.

Krajcik, B. J., & Merritt, J. (2012). Engaging Students in Scientific Practices: What does constructing and revising models look like in the science classroom? *Science Teacher, 79*(1), 38–41.

Michaels, S., Shouse, A. W., & Schweingruber, H. A. (2008). *Ready, Set, Science!*. Washington, D.C., USA: The National Academies Press.

Mikeska, J. N., Anderson, C. W., & Schwarz, C. V. (2009). Principled reasoning about problems of practice. *Science Education*, *93*(4), 678–686.

NRC. (2007). *Taking Science to School: Learning and Teaching Science in Grades K-8*. (R. A. Duschl, H. A. Schweingruber, & A. W. Shouse, Eds.) (Committee.). Board on Science Education, Center for Education. Division of Behavioral and Social Sciences and Education. Washington, D.C.: The National Academies Press.

NRC. (2012). *A framework for K-12 Science Education. Practices, Crosscutting Concepts and Core Ideas*. Washington, D.C.: The National Academies Press.

Osborne, J. (2014). Teaching Scientific Practices: Meeting the Challenge of Change. *Journal of Science Teacher Education*, *25*(2), 177–196.

Osborne, J., & Dillon, J. (2008). *Science Education in Europe: Critical Reflections*. London, UK: Nuffield Foundation.

Reiser, B. J. (2013). What Professional Development Strategies Are Needed for Successful Implementation of the Next Generation Science Standards? Retrieved from http://www.k12center.org/rsc/pdf/reiser.pdf

Schwarz, C. (2009). A Learning Progression of Elementary Teachers ’ Knowledge and Practices for Model-Based Scientific Inquiry.

Schwarz, C. V., Reiser, B. J., Davis, E. A., Kenyon, L., Achér, A., Fortus, D., … Krajcik, J. (2009). Developing a learning progression for scientific modeling: Making scientific modeling accessible and meaningful for learners. *Journal of Research in Science Teaching*, *46*(6), 632–654.

MOTIVATION FOR CHOOSING *PHYSICS* TEACHER EDUCATION – AN INSTRUMENT ADAPTATION STUDY

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Abstract: The FEMOLA (Pohlmann & Möller, 2010) is a German instrument to retrospectively measure motivations for choosing teacher education based on the expectancy value model. In a qualitative study conducted by the authors within a content analysis framework, a synthesis of subject specific and educational interests was identified as a major category of its own. From a methodological perspective we were curious whether the existence of this category could be cross-validated by statistical approaches. In addition the reasons for students' choices of *physics* teacher education are helpful to us in order to be better prepared for the needs and expectations of our students. We therefore tried to adopt the FEMOLA as an efficient instrument allowing to measure motivations for choosing *physics* teacher education. Results show that it is possible to develop an adopted instrument, that includes our new construct and still meets the criteria of reliability and validity for the surveyed German physics teacher students.

Keywords: FEMOLA, physics teacher career choice, motivation

INTRODUCTION

The relevance of knowing about motivations for (physics) teacher career choices

To become a teacher or not to … This decision is a pivotal decision for the personal future of many young men and women, since career choices interact with identity and influence general life satisfaction (Alberts et al., 2003). But what lets someone make this decision, what are the motivations for this particular career choice? This question is an interesting one from an individual perspective. In addition to this the reasons why young people choose to become a *teacher* is also of interest from a social perspective, since teachers contribute strongly to the development and education of a next generation. Therefor not surprisingly, studies about the choice of higher education have been conducted from many diverse perspectives, such as economics, psychology and sociology. Within research about the teacher profession, motivations for teacher career choices can be considered to be a well established field of research.

Understanding why students want to become *physics teachers* can draw on general research about the choice to become a teacher as well as research on why people are getting involved with science.

Focusing on Germany (Rothland, 2011), one can find, that "enjoying to work with kids" is the single most important reason for becoming a teacher, while the importance of other factors varies over time and between different cohorts. The scope of these factors include social responsibility of the teacher (Oesterreich, 1987) on one hand and intellectual stimulation (Sinclair, 2008) on the other hand. A list of further identified factors includes (Alexander, Chant, & Cox, 1994; Joseph & Green, 1986; Kyriacou & Coulthard, 2000; Meinhardt, Krey & Rabe, 2013; Moran, Kilpatrick, Abbott, Dallat, & McClune, 2001; OECD, 2005; Sinclair, Dowson, & McInerney, 2006):

- working with children,

- subject specific interest,
- making a social contribution,
- making a difference,
- job security,
- job benefits,
- enjoyment of teaching,
- compatibility with other interests and activities,
- compatibility with family life,
- self-education, etc.

There seems to be a general tendency that intrinsic motives are more strongly ascribed to than extrinsic motives. Sex differences if found at all cannot be generalized. Teacher students that intend to teach at high-school level seem to be motivated more strongly by their interest in the subject-content they are going to teach than those future teachers in the primary school track. While “content matter” and “working with kids” are important factors they are considered independently and clearly distinct from each other in the studies we are aware of.

Methodological Approaches to study (physics) teacher career choices

While a majority of the research conducted in the past made use of quantitative methods in a cross sectional design, there are insightful new approaches that make use of qualitative methods in longitudinal designs (e.g. Holmegaard et al., 2012). Although we greatly appreciate this kind of research and find it informative concerning the actual process that leads to a certain decision it cannot be considered the main stream in research on teacher career choices, where retrospective surveys with closed Likert items and quantitative analysis approaches are widely spread. This is probably due to the interest in motives of large groups of students that are easier to survey by questionnaires developed for quantitative analysis. Furthermore instruments used in these surveys are rarely state of the art in terms of being the result of a validation or instrument development study. In contrary, often adhoc developed separately evaluated items are used and only rarely are factorial structures considered or even confirmed (Terhart, Czerwenka, Ehrich, Jordan, & Schmidt, 1994). In some cases, there are open ended questions used to make up for limitations of closed Likert items or to generate a pool of items. Only rarely item construction or study design are informed by (psychological) theories. One psychological theory that has been utilized in the field of career choices, however, is the expectancy value model (e.g. Eccles, 2005). In the English speaking community the work on “Factors Influencing Teaching Choice” or in short FIT-Choice (Watt & Richardson, 2008) is widely known. A German instrument, that applies the expectancy value theory in a similar way is the so called FEMOLA (a German abbreviation for “Questionnaire on motivations for choosing teacher education”; translated by the authors (T.R., O.K.). The FEMOLA (Pohlmann & Möller, 2010) was developed by educational psychologists for the retrospective survey of teacher students about their career choice. It includes three factors within the value component and 3 factors within the expectation component. See Figure 1 for factors, numbers of items per factor and exemplary item stems. All items have to be evaluated on a 4-level scale (1 = do not agree at all, 4 = fully agree).

To sum up, although a lot of research has been conducted we are far away from seeing clear in the field of teacher career choices: “The current literature is unclear on *why* people choose teaching careers and why many leave the profession in their early years, is predominantly *empirically rather than theoretically driven*, and has generally failed to draw on the motivation literature. […] research has *lacked an integrative theoretical framework* to guide the selection and organization for influential factors, proceeded in a somewhat piecemeal fashion using poorly defined constructs, and with individual researchers frequently investigating *subsets of possible factors*." (Richardson & Watt, 2006; our emphasis)

FEMOLA (Pohlmann & Möller, 2010)
Questionnaire on motivations for choosing teacher education

value

educational interest, 6 items: e*njoying to work with kids*

subject-specific interest*,* 5 items: *learn more about my subject*

utility, 8 items: *lots of holidays, decent income* as a teacher

expectation

ability beliefs, 5 items: *I can explain well.*

low difficulty of the study*,* 4 items: *study is not too demanding*

social influences*,* 5 items: family's and friends' advices

Figure 1. Factor structure as assumed in the FEMOLA, number of items per factor, example item stems.

BACKGROUND OF OUR STUDY AND RESEARCH QUESTIONS

For this paper we relate to a quantitative method within a cross sectional retrospective study approach, trying to specify an existing instrument (the FEMOLA) to measure motivations for choosing *physics* teacher education. This attempt was grounded in our wish to learn about the students entering the physics teacher education program at our university. In order to do so we started with a qualitative study in which we surveyed our students with a questionnaire using open ended questions. The research presented here, hence is part of a larger project. Students' answers to the question "Please describe, why you have decided to get involved in the physics teacher program." were categorized using a content analysis approach. Students were also asked to identify their three most decisive reasons (Meinhardt u. a., 2013).

During the inductive process of category development, we found many answers that could be summarized in categories well established in the literature, e.g. the factor *educational interest* and *subject specific interest* were evident, as expected. However, beside the well known factors covered in e.g. the FEMOLA, we identified a rather large number of codings that revealed a synthesis of subject specific and educational interests, e.g. a student not stating that physics is important and also not stating that teaching kids is meaningful, but teaching physics to kids is what is important and meaningful. We call motives of this kind of interest *"fachdidaktisch" (fd)*, since it combines and synthesizes subject (Fach) specific and educational (didaktisch) motivations to a new quality. The factor could perhaps be considered to reflect the glimpse of an integrative *pedagogical content perspective* (pcp) in the students' answers. Without being deeply anchored in Shulman's theory, we are going to use this terminology for this article in order to refer to the kind of motivations described above. Since this seems to be a relevant information, that helps to better understand our students' motivations and since in general we are in need to get a quick overview by means of questionnaires using closed Likert items, we were wondering, whether this would be possible at all. A more general concern that guided our research is the wish to have a physics teacher specific instrument, which seems reasonable, knowing that subject interest is a very influential factor. To sum up, we try to answer the following research questions:

1. Is it possible to operationalize the new construct fd interest into a set of items that allow a valid and reliable measurement?
2. Is it possible to adopt the FEMOLA items to obtain a physics specific version and still remain a valid and reliable instrument.
3. Can an additional construct "fachdidaktisch" (pedagogical content perspective) be integrated in the FEMOLA?

METHOD

First we developed items to operationalize a value factor as well as an expectancy factor according to our new construct – the *pedagogical content perspective (pcp)*. For students enrolled in the physics teacher program at Potsdam University, Germany, we surveyed in retrospect the reasons for their choice of study to become a physics teacher. The survey took place in week four of the winter semester 2011 and 2012 and included 208 students (162 males) of semester 1 and 3, most of them aiming to become K12 teachers. We made use of an adopted physics specific version of the FEMOLA, by substituting words of the the original item stems – *subject* by *physics* and *teacher(s)* by *physics teacher(s)*. We also added the above mentioned items for our new construct, one factor within the value component and one within the expectancy component. See Figure 2 for details. All items had to be judged on a 4-level Likert scale ranging form 0 "don't agree at all" to 3 "agree fully".

adopted FEMOLA (Pohlmann & Möller, 2010) as used in our study
Questionnaire on motivations for choosing teacher education

value

educational interest (edi), 4 items: e*njoying to work with kids*

subject-specific interest (ssi), 5 items: *learn more about physics*

utility (uti), 7 items: *lots of holidays, decent income as a physics teacher* (factor found to include two sub factors – financial (fi) and social (so))

pedagogical content perspective (pcp-v), 4 items: *help students to understand physics*

expectation

pedagogical content perspective (pcp-e), 6 items: *I can explain physics well.* (includes physics specific ability beliefs (4 items))

~~**low difficulty of the study**, 4 items: *physics is not too demanding*~~

social influences (sin), 3 items: *family's and friends' advices*

Figure 2. Factor structure of our adopted physics specific FEMOLA version including a factor "pedagogical content perspective" integrating educational and subject specific interest as suggested by a qualitative pilot study, items per factor and exemplary item stems.

To answer our research questions a structural equation modelling approach is used, we make use of the confirmatory factor analysis techniques as implemented in MPLUS 7.3. Due to non-normal distributions and missing values a robust Maximum Likelihood Estimator (rMLE) is used. Model fit is evaluated according to general standards at different levels of the model. E.g. factor loadings are carefully considered and we made sure that they were always >0.5 or (in two cases) at least not lower than in the original FEMOLA (cf. Pohlmann & Möller, 2010). However, in this paper we only present values for global fit criteria and make use of the following criteria to evaluate overall model fit such as χ^2/df<2.5, TLI>0.90, RMSEA<0.08. (These are the indices used to evaluate the original FEMOLA as well (Pohlmann & Möller, 2010)), CFI>0.90 and SRMR<0.08. We first check our newly developed scales consisting of 6 items for the *pedagogical content perspective* (pcp) *expectancy component* and 4 items for our *pcp value component*. After that we establish an acceptable baseline model that if possible is as good as the original FEMOLA and against which we could compare our modifications (models 1 to 3). We then try to integrate our new factors - the expectancy component of our pedagogical content perspective, which replaces the original factor ability beliefs, and the value component of our pedagogical content perspective (model 4). For theoretical reasons, we also test whether the theoretical assumption of second order expectancy and value factors can be supported empirically (model 5). Finally, an explorative analysis that aims for second order factors “intrinsic” and “extrinsic” will be conducted (model 6).

RESULTS

For the original FEMOLA consisting of only the six first order factors (model 0), the following fit indices were reported: $\chi^2_{459} = 615.17$, TLI=0.93, RMSEA=0.047, scale reliability $\alpha_{Cronbach} \geq 0.74$ (Pohlmann & Möller, 2010, p. 81).

Our new scales hold against the criteria mentioned above. For our expectancy component factor loadings were between 0.50 and 0.79, $\chi^2_7 = 17.74$, TLI=0.96, RMSEA=0.069, $\alpha_{Cronbach} = 0.82$ and for our value component factor loadings are between .45 and .80 (with the loading of one item <.50), $\chi^2_2 = 2.30$, TLI=0.99, RMSEA=0.027, $\alpha_{Cronbach} = 0.78$.

Our physics specific version of the FEMOLA (considering the same - but specified, if reasonable - items, model 1) revealed the following results $\chi^2_{309} = 549.06$, TLI=0.85, RMSEA=0.061 and confronted us with an unacceptable model fit. A closer look revealed three problematic items that we removed as well as a problem with the utility factor. Much more variance could be explained by assuming a two dimensional substructure of this factor. Splitting the utility factor into two sub factors, namely “financial utility” (3 items) and “social utility” (4 items) improves the model: $\chi^2_{308} = 546.61$, TLI=0.91, RMSEA=0.048 substantially (model 2).

Further analysis showed, that the factor “low difficulty” is somewhat useless. This is understandable, if one considers items like “I have chosen to become a physics teacher student, because studying physics is easier than other subjects” contradicting the public opinion about physics as one of the hardest subjects. We therefore removed this factor from our model for further analysis (model 3) which improved the model fit again: $\chi^2_{219} = 302.84$, TLI=0.94, RMSEA=0.043.

Including our two new *pedagogical content perspective* factors into our model (pcp-expectancy replacing the factor “ability beliefs” and pcp-value being an addition) we obtained the following fit indices for model 4: $\chi^2_{361} = 508.64$, TLI=0.94, RMSEA=0.044.

Introducing 2nd order factors *expectancy* and *value* (model 5, as depicted in figure 2) leads to an acceptable model with $\chi^2_{369} = 564.19$, TLI=0.91, RMSEA=0.050 and a correlation between the main factors of 0.72^{**}.

For explorative purposes only introducing 2nd order factors *extrinsic* (loading on the social/financial utility factors as well as social influences) and *intrinsic* (the rest of the factors) results again in an acceptable model fit: $\chi^2_{369} = 517.43$, TLI=0.93, RMSEA=0.044, correlation between the main factors not significant (model 6). More details about the described model fits can be found in table 1.

Finally, we also calculated correlations between the constructs used in model 4-6 and the ability beliefs as used in the FEMOLA and in models 0-3 (table 2).

Table 1. Model fit indices for the factors and models described in the text.

	χ^2	df	χ^2/df	p	CFI	TLI	RMSEA [90% CI]	SRMR
pcp-e	17.74	9	1.97	.04	.98	.96	.069 [.015; .116]	.032
pcp-v	2.30	2	1.15	.02	.99	.99	.027 [.000; .143]	.017
model 0	615.17	459	1.34	-	-	.93	-	-
model 1	549.06	309	1.78	.00	.87	.85	$.061^{*}$ [.053; .069]	.068
model 2	456.61	308	1.48	.00	.92	.90	$.048^{*}$ [.039; .057]	.063
model 3	302.84	219	1.38	.00	.95	.94	.043 [.030; .054]	.059
model 4	508.64	361	1.41	.00	.94	.93	$.044^{*}$ [.035; .053]	.062
model 5	564.19	369	1.53	.00	.92	.91	$.050^{*}$ [.042; .059]	.084
model 6	517,43	369	1.40	.00	.94	.92	$.044^{*}$ [.035; .053]	.070

Table 2. Correlations (Kendalls Tau b) between factors used in models 4-6 plus factor ability beliefs.

	mean (sd)	abe	pcp-e	pcp-v	ssi	sin	edi	ut-fi	uti-so
abe (α=.60)	2.27 (.44)	-							
pcp-e (α=.78)	2.08 (.44)	$.418^{**}$	-						
pcp-v (α=.82)	2.50 (.49)	$.176^{**}$	$.374^{**}$	-					
ssi (α=.86)	2.39 (.52)	$.169^{**}$	$.322^{**}$	$.471^{**}$	-				
sin (α=.70)	.91 (.67)	n.s.	$.136^{*}$	n.s.	n.s.	-			
edi (α=.86)	2.23 (.61)	$.232^{**}$	$.200^{**}$	$.178^{**}$	$.141^{**}$	$.130^{**}$	-		
uti-fi (α=.80)	1.89 (.62)	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	-	
uti-so (α=.83)	1.68 (.70)	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	$.360^{**}$	-

DISCUSSION

We can state that in response to research question 1 it is possible to develop scales that can be used to measure a pc value and expectancy component. Empirical data support the assumption of a unidimensional, reliable operalization of our constructs. Correlations as shown in table 2 support the adequacy of our constructs (e.g. highest correlation between pcp-e and abe).

Research question 2 can be positively answered as well. It is possible to develop a physics specific version of the FEMOLA (model 2). However, to achieve acceptable model fit we needed to differentiate the utility factor into two subfactors (social and financial utility). The model improves significantly (above the values of the original FEMOLA), if the factor low difficulty is eliminated. From a content perspective this makes sense, since physics is known to be a rather demanding subject and while being of some importance in a questionnaire aiming at teacher students for different subjects, it is somewhat unnecessary for physics teacher students.

With regard to our third research question, we were able to integrate a pcp-value and a pcp-expectancy the latter one integrating physics specific ability beliefs and therefore replacing the factor of the original FEMOLA. Introducing these two factors results in an even better fit of the model (model 4). This is a substantial advancement when interested in physics teacher students' specific motivations for choosing a career as a physics teacher. The high means (table 2) for these factors show, that they are highly relevant to our students.

The following is beyond our research questions, but we were also able to accept a 2nd order factor model using *expectancy* and *value* as the main factors (model 5). This was not the case in the original FEMOLA, but seems to support the theoretical assumptions namely the expectancy value framework. However, on the other hand the fit for model 5 is not as good as it is for model 4, which indicates that the introduction of the theory based factors reduces the model fit significantly. This would suggest to rethink the adequacy of the expectancy value framework for studies of this kind.

Finally, we also find, that 2nd order model 6 with main factors *intrinsic* and *extrinsic* yields an acceptable model fit, better than the fit of model 5 and almost as good as model 4. This would further support the potential inadequacy of the expectancy value framework for our study. A look at the means reveals that intrinsic motivations in general are rated higher than extrinsic motivations (see table 2).

This quantitative piece of research was informed and inspired by qualitative findings, an approach that proved to be fertile. From an international perspective it remains an open question whether our importance of the pedagogical content perspective is a German thing only.

REFERENCES

Alberts, C., Mbalo, N. F. & Ackermann, C.J. (2003). Adolescents' perception of the relevance of domains of identity formation: A coross-cultural study. *Journal of Youth and Adolescence*, 32, 169-184.

Alexander, D., Chant, D., & Cox, B. (1994). What Motivates People to Become Teachers. *Australian Journal of Teacher Education*, *19*(2), 40–49.

Brown, T. A. (2006). *Confirmatory Factor Analysis for Applied Research*. New York & London: The Guilford Press.

Holmegaard, H. T., Madsen, L. M., & Ulriksen, L. (2012). To Choose or Not to Choose Science: Constructions of desirable identities among young people considering a STEM higher education programme. *International Journal of Science Education*, (October 2013), 1–30.

Joseph, P. B., & Green, N. (1986). Perspectives on Reasons for Becoming Teachers. *Journal of Teacher Education*, *37*(6), 28–33.

Kyriacou, C., & Coulthard, M. (2000). Undergraduates' views of teaching as a career. *Journal of Education for Teaching: International research and pedagogy*, *26*(2), 117–126.

Meinhardt, C., Krey, O., & Rabe, T. (2013). Studienwahlmotive angehender Physiklehrkräfte. Qualitativ inhaltsanalytische Auswertung einer offenen, retrospektiven Befragung. *PhyDid A*, 18–35.

Moran, A., Kilpatrick, R., Abbott, L., Dallat, J., & McClune, B. (2001). Training to teach: Motivating factors and implications for recruitment. *Evaluation & Research in Education*, *15*(1), 17–32.

OECD. (2005). *PISA 2003. Technical Report*. doi:10.1787/9789264010543-en

Oesterreich, D. (1987). *Die Berufswahlentscheidung von jungen Lehrern*. Berlin.

Pohlmann, B., & Möller, J. (2010). Fragebogen zur Erfassung der Motivation für die Wahl des Lehramtsstudiums (FEMOLA). *Zeitschrift für Pädagogische Psychologie*, *24*(1), 73–84.

Richardson, P. W., & Watt, H. M. G. (2006). Who Chooses Teaching and Why? Profiling Characteristics and Motivations Across Three Australian Universities. *Asia-Pacific Journal of Teacher Education*, *34*(1), 27–56.

Rothland, M. (2011). Warum entscheiden sich Studierende für den Lehrerberuf? Interessen, Orientierungen und Berufswahlmotive angehender Lehrkräfte im Spiegel der empirischen Forschung. In E. Terhart, H. Bennewitz, & M. Rothland (Hrsg.), *Handbuch der Forschung zum Lehrerberuf* (S. 268–295). Münster [u.a.]: Waxmann.

Sinclair, C. (2008). Initial and changing student teacher motivation and commitment to teaching. *Asia-Pacific Journal of Teacher Education*, *36*(2), 79–104.

Sinclair, C., Dowson, M., & McInerney, D. (2006). Motivations to teach: Psychometric and longitudinal perspectives. *Teachers College Record*, *108*(6), 1132–1154.

Terhart, E., Czerwenka, K., Ehrich, K., Jordan, F., & Schmidt, H. J. (1994). *Berufsbiographien von Lehrern und Lehrerinnen*. Frankfurt a. M.: Lang.

Watt, H. M. G., & Richardson, P. W. (2008). Motivations, perceptions, and aspirations concerning teaching as a career for different types of beginning teachers. *Learning and Instruction*, *18*(5), 408–428.

PROFESSIONALIZATION THROUGH PRACTICAL TRAINING – APPLICATION OF PCK WITHIN A PHYSICS STUDENT LAB

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Abstract: In 2004 the Standing Conference of the Minister of Education and Culture Affairs released the standards for teachers' education in Germany. The standards should help to improve the pre-service teacher education by a new competence orientation for the education contents and the implementation of more practical training in the pre-service teacher education. Due to the new competence orientation several researchers have tried to define and model professional teachers' competence. Most of the works are based on Shulmans definition and divide the professional knowledge of teachers into content knowledge, pedagogical content knowledge and pedagogical knowledge (Shulman, 1989; e.g. Baumert, 2010). With the competence orientation practical training became an important part of the pre-service teacher education. To improve the teacher education and to fulfil the standards the science departments of the university Würzburg has implemented the student lab as a tool of practical training in the pre-service teacher education. In the student lab seminar the pre-service teachers have to design experimental stations of a certain topic and plan the performance of the stations in the student lab. After the preparation several performances with different school classes take place. Subsequent to every performance the pre-service teachers get feedback by their peer group and the instructors. The feedback helps the pre-service teachers to change their experimental station or their performance before the next one takes place. We like to know in our survey if the student lab is a good tool of practical training to improve the professional knowledge of the pre-service teachers. The focus of the survey is the application and the development of the *pck* during the student lab. First results show a positive development of *pck* and knowledge about students' conception in one semester. Also the application of *pck* is different between the several pre-service teachers.

Keywords: pedagogical content knowledge, physics pre-service-teacher education, teacher professionalization, student lab

INTRODUCATION

The results of PISA initiated a wide-stretched discussion about the pre-service teacher education in Germany. The result of this discussion are the standards for pre-service teacher education released by the Standing Conference of the Ministers of Education and Culture Affairs of the Countries in the Federal Republic of Germany in 2004. The standards should help to improve the pre-service teacher education by implementing professional competencies of teachers. In 2010 Baumert found evidences that the professional teaching competence of teachers have an impact on the students' performance (Baumert, 2010, Kunter, 2011). According to the standards pre-service teachers need to "know general and specialised didactics and know what is important to plan lessons". Furthermore they should be able to "link content and pedagogical content arguments and plan and design lessons". The Ministers point out that these competences could be learned by "testing and reflection a theoretical concept in (…) simulated lessons, natural lessons or at out-of-school learning facilities" (KMK, 2004). This shows the need for more practical training in the pre-service teacher education. However, the practical training needs to fulfil certain conditions in order to have a positive impact on the professionalization of pre-service and in-service teachers. Tschannen-Moran and Makrinius mentions a long preparation time and much time for reflection as just one condition for good practical training (Tschannen-Moran, 1998, Makrinius, 2013).

Additionally, the training situations should not overstrain the pre-service teachers. There are different ways to create appropriate situations, for example the pre-service teachers, as you see in the microteaching, can supervise only little groups of students in the same time, or always avoid the same content in every practical training time (Merglera, 2003). To fulfil the standards and the need for more practical training the science departments of the university Würzburg implemented the student lab as a version of practical training in the science teacher education (Völker, 2009 and Elsholz, 2014). Part of this proceeding is the question whether the student lab is a good tool of practical training and whether there is an impact between the professionalization and the student lab.

THEORETICAL BACKGROUND

With the release of the standards of education, competencies became an important word in the pre-service teacher education. Weinert defines competences as "*cognitive abilities and skills that individuals possess or can learn for solving problems, and the associated (…) motivational, volitional and social readiness and abilities that enable them to use these solutions responsibly and successfully in a variety of situations*." (Weinert, 2001). Furthermore, Weinert expands this general definition of competence to the action field of teaching. In his concept of teachers' professional knowledge, a teacher needs to combine "*intellectual abilities, content-specific knowledge, cognitive skills, domain-specific strategies, routines and subroutines, motivational tendencies, volitional control systems, personal value orientations and social behaviour*" (Weinert, 2001). According to this definition, several models and evaluations of teachers' professional knowledge were examined by the researchers. A common model is the model of teachers' professional competences by Baumert and Kunter (COACTIV project) shown in the figure 1 below.

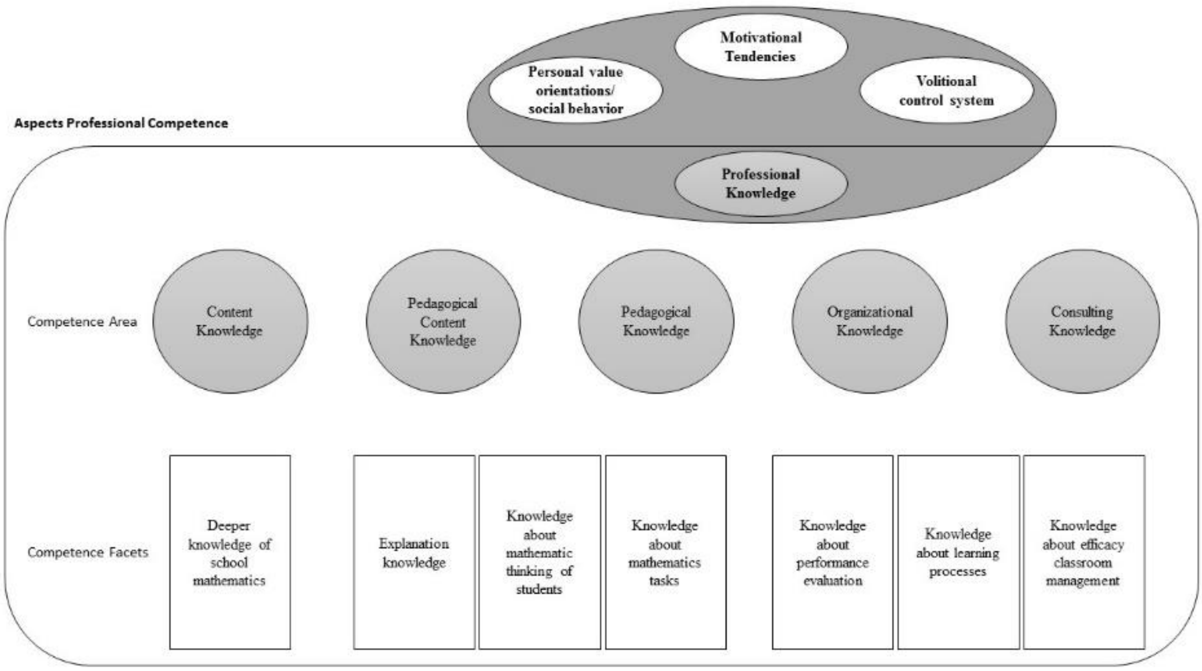

Figure 1. Model of teachers' professional competence by Baumert and Kunter (COACTIV project) (Kunter, 2011).

It clearly shows, that Baumert and Kunter stay close to the definition of Weinert and divide the aspects of professional competence in *personal value orientation and social behaviour, motivational tendencies, volitional control systems and the professional knowledge*. Furthermore, the professional knowledge is divided into content knowledge (*ck*), pedagogical content knowledge (*pck*), pedagogical knowledge (*pk*), the organizational knowledge and the consulting knowledge. Even though all dimensions are important for the teachers' profession, *pck* has a positive impact on the student's performance in particular (Ball, 2001). *Pck* is the knowledge that helps teachers to structure, to explain, to describe and to link scientific contents, this abilities are the differences between an expert and a teacher (Shulman, 1989). This definition by Shulman is the base of many works on *pck*. Magnusson and Borko extend the definition and divides it in five components of *pck*: Science teaching orientation, knowledge of students understanding of science, knowledge of science instructional strategies, knowledge of science curriculum and knowledge of assessment in science (Magnusson, 1999). Based on the description of Magnusson, Kröger and Neumann created a model of *pck*. They divided *pck* into three dimensions: the scientific content, the state of knowledge and the *pck*-facets. Furthermore, the *pck*-facets are divided into assessment, instructional strategies, curriculum, and student cognitions (Kröger, 2013). Underlying are several other models of *pck*, for example the projects ProwiN (Borowski, 2010) and ProfileP (Kulgemeyer, 2015).

RESEARCH BACKGROUND AND METHODS

Student lab as a version of practical training for the pre-service teacher education

To improve the pre-service teacher education and to fulfil the expectations for practical training claimed in the standards of teacher education the science departments of the University Würzburg implemented the student lab in the pre-service teacher education. In 2009, the science departments found the M!ND Center and created the student lab as a practical training course for the pre-service teachers. The student lab should link the three areas pre-service teacher education, school and research. The precise realization of the student lab seminars belongs to the particular departments. In the physics department the pre-service teachers have to visit the student lab course in the sixth semester (Völker, 2009). Around 20 pre-service teachers participate in the course every semester in the course. Every student lab has different experimental stations related to the main topic of the lab. For example, the student lab "*optics*" contains three experimental stations: the human eye, reflection and light and shadow. The seminar is divided into two parts: a preparation course and a practical training. In the preparation course, the pre-service teachers design in groups one experimental station for a certain subtopic related to the main topic. The experimental station includes different experiments with instructions and accompanying material e.g. cloze tests for backup the content. Furthermore, the pre-service teachers have to unify the single experimental station to one student lab and digitalise all materials for iPads tablets with which the students are going to work. The pre-service teachers have to plan the performance with the school classes. The whole preparation period lasts ten weeks and is followed by the practical training. In the practical training, four to five school classes visit the student lab. The students are divided into small groups of three to five students to perform the student lab. The pre-service teachers supervise the working process of the students at their stations. After finishing, the students change the experimental stations and the pre-service teachers get new students for supervising. After every performance, a reflection talk with the experts (instructors) and the peer group (fellow pre-service teachers) takes place. Then the pre-service teachers get time to change their experimental station and the lab-manual before the next visit of a school class. As shown above, a practical course has to fulfil different requirements. It is necessary to ask whether the student's lab match these requirements. The student lab seminar has a ten weeks lasting preparation period where the pre-service teachers can focus on one physics topic. There is enough time for reflection after every performance with the school classes. The practical situations for the pre-service teachers are moderate, because the pre-service teachers supervise only four to five students and perform always the experimental station they have designed themselves. Hence, the student lab fulfil all requirements for a good practical training.

Research questions

Although the student's lab fulfils the conditions to be a suitable tool of a practical training course, its effect on the professional knowledge is unknown and should be investigated in the following research project. As the professional knowledge of teachers is a wide area the focus of the investigations is the pedagogical content knowledge. The following questions should be answered:

1. Does the *pck* develop along the student lab?
2. Which knowledge do the pre-service teachers use to design the experimental stations and to plan the performances with the school classes?

Research Design and Methods

The survey takes place between the winter term 2014/15 and the summer term 2016. In the four semesters, around 60 pre-service teachers participate in the survey. To investigate the impact from the student lab on the *pck* of the pre-service teachers, a mixed method approach is used. At the beginning and the end of the course, the pre-service teachers have to answer two paper and pencil tests to examine their *pck*. Additionally, the pre-service teachers have to keep logbooks to know more about the knowledge they use to design their experimental station and to plan the performances with school classes. They have to answer three questions. The first question has to be answered before the first performance with a school class takes place. The second question has to be answered after the first performance and the last question has to be answered at the end of the semester.

The first paper and pencil test analysing the pck consists of items from the project KiL by the IPN Kiel (Kröger, 2013). The pre-service teachers have to answer 20 items for the *pck* and 10 items for the *ck*. The content of the *ck* test belongs to the topic in the student lab. The *pck* test contains three items for the assessment, eight items for instructional strategies, four items for knowledge about the curriculum and five items about students' cognitions.

In the second paper and pencil test the knowledge about students' conceptions are examined. The items belong to the Diagnoser project by the NSF and the University Washington (Thissen-Roe, 2004, www.diagnoser.com). The second paper and pencil test contains 13 items about the specific students' conceptions. An example of a question is given in the figure 2 below.

Example 2 (Question 10)

Cubes A and B are the **same size** and made of the **same material**. Two identical samples of water, each in a beaker with a thermometer, are at room temperature.
One cube is placed in each water sample. After a few minutes, the thermometers are checked.
The temperature of the water sample with Cube A increased by 10°C.
The temperature of the water sample with Cube B increased by 20°C.
What can you conclude about energy in this situation?

○	**Cube B started with more energy than Cube A.**	**03**
○	**Nothing; temperature changes do not require energy.**	**62**
○	**Cube A and Cube B started with the same amount of energy.**	**62**
○	**Energy was produced by the reaction between water and the cubes.**	**51**

Select a wrong answer and write down the underlying students conceptions!

Facet-Cluster (Question 1)

03 "The student understands that different sources of energy can have different amounts of energy and the amount of energy can be indicated by changes and/or by comparing relative changes. (Energy changes that occur during an interaction can be measured.)"

51 "Potential energy is created as a product of some situation/reaction."

62 "Temperature changes (e.g. as a result of light/sunlight interactions with objects) are not seen as involving energy."

Figure 2. Example of an item from the paper and pencil test which belongs to the Diagnoser project. The item is on the left side, the coding on the right side (www.diagnoser.com).

The items look nearly the same in every test. A situation is described and there are different ways to answer. The pre-service teachers have choose a wrong answer and describe the underlying student conception for the answer they chose. Every answer is linked to a student concept which is called facet. These facets are developed by the Diagnoser project (Thissen-Roe, 2004). To analyse the second paper and pencil test, the facet clusters are used as a coding manual.

In addition to the paper and pencil tests, the logbooks help to analyse the application of *pck*. The logbooks are analysed by using the qualitative content analysis. In the first logbook question, the pre-service teachers have to describe the design and development of their experimental stations and the planning of the student's lab time. In the second question, the pre-service teachers describe the first performance of the school classes and the changes they made on the manner of supervising and the setup of the experimental station. In the last question, the pre-service teachers describe considerable changes they make on the experimental stations and the manner of supervising in the student lab. For every question the pre-service teachers have to focus on the *pck* and the *ck* they apply to, for example the design of experimental station, to describe the first performance or the changes.

RESULTS

Until now 37 pre-service teachers participated in the survey, 19 from the winter term 2014/15 with the topic "energy" in the student lab and 18 from the summer term 2015 with the topic "optics" in the student lab. 67 percent of the participants are male. The pre-service teachers are in the fifth or sixth semester and 73 percent of them are enrolled in the program for teaching profession for higher education (in Germany called Gymnasium). 41% reached a C in their A level (Abitur), 46% a B and 13% an A. Sixty-five percent of the pre-service teachers took physics in A level (Abitur) and 60% of them reached an A.

Table 1 shows the sum score and the standard deviation for the *pck* knowledge examined by questionnaire 1. Looking at the sum score for the total statistic, it strikes that the sum score does not change. Instead the standard deviation increases from a value of $\sigma_{pre} = 2{,}99$ to a value of $\sigma_{post} = 3{,}70$. Because of this increase, it is necessary to differentiate the statistic in winter term and summer term. Looking at the winter term, it can be seen that the sum score has a negative tendency and the standard deviation increases from $\sigma_{pre} = 3{,}00$ to $\sigma_{post} = 3{,}94$. On the contrary, the sum score for the winter term increases from 9.86 to 11.41. The standard deviation stays the same. It seems to be that the decrease of the standard deviation of the total statistic is linked to the winter term.

Table 1. Sum score and standard deviation of the *pck* knowledge examined by paper and pencil test 1 for the total statistics, the winter term and the summer term.

	Total Statistic		**Winter term 2014/15**		**Summer term 2015**	
	Sum Score	σ	Sum Score	σ	Sum Score	σ
Pre test	10,15	2,99	10,43	3,00	9,86	3,05
Post test	10,56	3,70	9,54	3,94	11,41	3,05

Table 2 shows the correlations of the *pck* knowledge for the total statistic. By looking at the results, it is obvious that there is a significant medial correlation from the grade in A level of the *pck*. The correlation can be calculated for the pre- and the post-test and a little increase becomes obvious. The school type has no impact in the pre-test, whereas it shows a little significant impact in the post test. The physics grade in A level has a medium significant correlation in the pre-test, this correlation disappears in the post test. The practical training and experiences itself has a medium significant impact of the *pck* in the pre-test. The correlation for the practical experience and the practical training in the second practical study remain in the post-test, but the correlation for the educational experience disappears.

Table 2. Correlation between some variables and the *pck* for the total statistic.

Variables	Pck pre		Pck post	
	r_s	Sig.	r_s	Sig.
A Level Grade	-.567**	.000	-.666**	.000
School Type	-.311	.073	-.340*	.042
Physics Grade in A Level	.579*	.038	.240	.388
Educational Experience	.386*	.024	.186	.300
Practical Experience	.376*	.029	.389*	.025
Second Practical Study	.392*	.022	.408*	.014

Table 3 shows the sum score of every item for the knowledge about students' conceptions examined with the second paper and pencil test. Comparing the sum scores of the winter term for the knowledge about students' conceptions in "energy", the value nearly stays the same. With a maximum sum score of 13 it can be seen that most participants score more than half of the available points. This can be substantiate by a look at the average value of all items, where no value is under .53. In contrast the sum score for the summer term and the knowledge of students conceptions in "optics" shows a low value of 5.87 in the pre-test which increases to a value of 8.63 in the post-test. With a closer look on the average of the items, it can be seen that some items have a low score in the pre- and the post-test, for example item five. Some items have a high score in the pre- and the post-test, for example item four, and some items have a low score in the pre-test and a high score in the post test, for example item 13.

Table 3. Average and sum scores for the knowledge about students' conceptions in the winter term with the topic "energy" and the summer term with the topic "optics".

Winter Term Pre-Test ("energy")		**Winter Term Post-Test ("energy")**		**Summer Term Pre-Test ("optics")**		**Summer Term Post-Test ("optics")**	
Item SC	Mean	Item SC	Mean	Item SC	Mean	Item SC	Mean
1	.86	1	.72	1	.40	1	.56
2	.78	2	.61	2	.79	2	.91
3	.50	3	.53	3	.63	3	.72
4	.77	4	.80	4	.39	4	.88
5	.81	5	.78	5	.11	5	.09
6	.72	6	.65	6	.54	6	.50
7	.58	7	.53	7	.36	7	.44
8	.53	8	.59	8	.61	8	.59
9	.78	9	.68	9	.79	9	.84
10	.71	10	.77	10	.68	10	.84
11	.81	11	.79	11	.68	11	.81
12	.83	12	.77	12	.54	12	.70
13	.53	13	.56	13	.32	13	.83
Sum score	8.83	Sum score	8.64	Sum score	5.87	Sum score	8.63

In addition to the results of the paper and pencil test, some evaluated data of the first logbook question can be presented. The first logbook question is: "*Describe design and development of materials and experiments of your student lab station. Focus on the ck and pck you applicate during designing. Consider the requirements of the students*". The first analysis shows that most pre-service teachers do not apply any content knowledge during designing the experimental stations. Only one out of 19 pre-service teacher out of the energy topic in the winter term mentioned applied content knowledge. In the summer term (topic "optics") five out of 13 pre-service teachers applied content knowledge. Drawing from an example of the application of content knowledge about the human eye, one pre-service teacher writes about how to create a sharp image: "*The position of the image depends on the shape of the lens and the distance to the light source. This is why sharp images on near objects are at different positions than sharp images on far objects*".

By analysing the application of *pck*, quite more pre-service teachers are found who apply *pck* to different topics. In Table 4 all the different topics and the number of mentions are shown.

Table 4. Application of *pck* by counting the numbers of mentions and the topics of *pck* seen in the logbooks.

***Pck* Topics**	**Number of Mentions**	
	Winter Term (“energy”)	Summer Term (“optics)
Teaching Methods	1	12
Curriculum	9	14
Learning Aims	5	3
Media	16	10
Models	0	2
Students’ Conceptions	2	5
Own School Experience	5	2
Motivation & Interest	12	9
Educational Reconstruction	4	13
Evaluation	8	7
Experiments	17	8

Three examples for the topics curriculum, media and own school experience are described below. Many pre-service teachers in the winter and the summer term use the curriculum to describe the requirements for the students. In an example from one optics participant he/she thinks about the previous experience the students need: “*The topic „optics“is first discussed in the seventh grade at the physics lessons. No previous physics experience are necessary*”. Most of the pre-service teachers deal with the topic media, especially about dealing and the advantages and disadvantages of using new media: “*For the experimental station “glazing” a video was taped, which shows the instructions for the experiments. The advantage (…) is, the students can see how the experiment proceed and if there are unclarities they can rewind the tape*“. The deal with the topic “own school experience” is somehow difficult because most pre-service teachers mention it, like in this example: “*We didn’t employ any pck literature, we only use our own experience and intuition*”.

DISCUSSION AND CONCLUSIONS

Through the standards of the teacher education, education in Germany becomes more competence orientated. As the standards of teacher education prescribe the learning of these competencies during practical training in different types, the need for more practical courses in Germany increases. The science departments of the University of Würzburg tries to fulfil this provisions by implementing the student lab as a new version of practical training. As described above, the student lab fulfil all the requirements of a good practical training. The pre-service teachers have enough time to prepare the experimental stations and the situations they have to handle are moderate because they always perform the same experimental station and only supervising four to five students at the same time. Even if the student lab seems to be a good practical training, the seminar impact on the *pck* and the application of *pck* is yet unclear. To survey this impact a mixed method approach is used. Two paper and pencil teats are used to examine the *pck*, the first one is based on the project KiL, the second one is based on the project Diagnoser. While looking at the sum score of the tests and the average of the single items, it can be seen that the tests are well balanced and can be used. With a closer look at the *pck* questionnaire, there is no development for the total statistic but there is a negative tendency for the winter term group and an increase of the *pck* in the summer term group. Until now there is no reason to be found to explain this. To clarify if the results depend on the group of participants or on the topic, the survey in the next semester will take place with a different topic in the student lab. Looking at the correlations between the *pck* and the variables a medium and high significant between the *pck* and the grade in A level can be found. Even the practical trainings have an impact on the *pck* of the pre-service teachers. Looking at the knowledge about students' conceptions it can be seen, that the optics test is more difficult in the pre-test than the energy test. The difference disappears in the post-test because the sum score for the optics test increases from 5.87 to 8.63. The application of *pck* by the pre-service teachers can be analysed with logbooks. The pre-service teachers have to answer three different questions. The analysis to the first logbook question shows that the pre-service teachers apply different topics of *pck*, while designing their experimental stations. Both the participants of the winter and the summer term focus strongly on media while designing their stations. The reason for this might be that the pre-service teachers use iPads for the instructions and all materials. Another focus lies of course on experiments because the experiments are the center of every station. Many pre-service teachers write about the curriculum, because they need to match the state of knowledge of the students with the experiments as the logbook question requires.

To answer the research questions the statistics must be increased. It is also necessary to analyse the logbooks more in detail and to calculate structure equation models with the values of the questionnaires. At the end, the logbooks and the results of the questionnaires must be compared by using case analysis.

REFERENCES

Ball, D., Lubienski, S. et al. (2001). Research on teaching mathematics. In V. Richardson (Eds.), *Handbook of research on teaching. The unsolved problem of teachers‘ mathematics knowledge* (pp. 433-456).

Borowski, A., Neuhaus, A. et al. (2010). Professionswissen von Lehrkräften in den Naturwissenschaften (ProwiN) – Kurzdarstellung des BMBF-Projekts. *Zeitschrift für Didaktik der Naturwissenschaften*, *16*, 341-349.

Baumert, J., Kunter, M., Blum, W. et al. (2010). Teachers‘ mathematica knowledge, cognitive activation in the classroom, and students progress. *American Educational Research Journal*, *47* (1), 133-180.

Elsholz, M., Fried, S., Trefzger, T. (2014). Effects of gender and teaching practice in an out-of-school learning lab on academic self-concept of pre-service physics teachers. Teaching/Learning physics. In C. Fazio & R.M. Sperandeo Mineo (Eds.), *Integrating Research into Practice. Proceedings of the GIREP MPTL Conference 2014* (pp. 795-802).

Merglera, A.G., Tangena, D. (2003). Using microteaching to enhance teacher efficancy in preservice teachers. *Teach Education, 21* (2010), 199-210.

Konferenz der Kultusminister der Länder - KMK (2004). Standards für die Lehrerbildung: Bildungswissenschaften. Beschluss der Kultusministerkonferenz vom 16.12.2004.

Kröger, J., Neumann, K. et al. (2013). Messung professioneller Kompetenzen im Fach Physik. *Inquiry-based-learning – Forschendes Lernen, 33,* 533-535.

Kunter, M., Baumert, J. et al (2011). *Professionelle Kompetenz von Lehrkräften. Ergebnisse des Forschungsprogramms COACTIV.*

Magnusson, S., Krajcik, J. et al. (1999). Nature, sources, and development of pedagogical content knowledge. In J. Gess-Newsome & N.G. Lederman (Eds.), *Examining pedagogical content knowledge* (*pp.* 95-132).

Makrinus, L. (2013). *Der Wunsch nach mehr Praxis. Zur Bedeutung von Praxisphasen im Lehramtsstudium. Studien zur Schul- und Bildungsforschung*.

Riese, J., Kulgemeyer, C., et al. (2015). Modellierung und Messung des Professionswissens in der Lehramtsausbildung Physik. *Zeitschrift für Pädagogik, Beiheft 61*, 55-79.

Shulman, L.S. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher*, *15* (2), 4-14.

Thissen-Roe, A., Minstrell, J. et al. (2004). The DIAGNOSER project. Combining assessment and learning. Behavior Research Methods, *Instruments & Computers, 36*, 234-240.

Tschannen-Moran, M. et al. (1998). Teachers Efficiency – Its Meaning and Measure. *Review of Educational Researcher, 68* (2), 202-248.

Völker, M., Trefzger, T. (2009): Lehr-Lern-Labore zur Stärkung der universitären Lehramtsausbildung. *PhyDidB- Beiträge zur DPG-Frühjahrstagung*, . http://www.phydid.de/index.php/phydid-b/article/view/173/275 (state 10/2015).

Weinert, F.E. (2001). A concept of competence. A conceptual clarification. In D.S. Rychen & L.H. Salganik (Eds.), *Defining and selecting key competencies* (pp. 45-65).

www.diagnoser.com (Stand 13.10.2015).

HANDS-ON EXPERIMENTS IN THE PRACTICUM: CRITICAL ISSUES FOR INITIAL TEACHER EDUCATION

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Abstract: Hands-on experiments are usually assumed as consistent underpinnings for initial teacher education, however, they have been uncritically appropriated and in the daily life of Science education, little room is left for understanding the actual role of hands-on experiments in initial teacher education. This study focuses on critically evaluating the uses of hands-on experiments in Practicum, particularly examining the major challenges that student teachers face in implementing such approach as well as the possible contributions and limitations of hands-on experiments to initial teacher education. This is a yearlong ethnographic research conducted in 2010 with multiple data sources. We examine the Practicum activities which aims at articulating the specific content matter – in this case Physics, pedagogical theory provided mainly by the Faculty of Education, and the practice performed at school. Practicum combined with hands-on experiments is certainly a complex issue, which requires a framework able to deal with dynamic, complex and multi-level objects. In this scenario, cultural-historical activity theory is particularly valuable. As the research results indicate, hands-on experiments demand from student teachers an accurate, deep and solid disciplinary knowledge. Whereas it is the strength of this approach, it also shifts student teachers' focus mostly toward disciplinary aspects leaving pedagogical aspects aside. Furthermore, as the research results indicate, if taken uncritically, the very same features of hands-on approach employed by novice teachers might turn out to be a weakness. To sum up, we agree with the current literature about the benefits of hands-on approach in Science classrooms. Nevertheless, it also presented as complex and quite demanding for student teachers, who needs even more support and guidance in the Practicum.

Keywords: Practicum, Initial Teacher Education, Physics Education, Hands-on experiments.

INTRODUCTION

Recently, Fazio and colleagues (2010) have underlined that practice and its potentialities for initial teacher education (ITE) remains overlooked. Even though policy makers are progressively increasing time for tasks carried out in the field, little support is provided for schools and universities to improve a hands-on experiments to transform Practicum into an effective and shared activity. This complex activity, *Practicum,* which aims to interconnect knowledge and practices from different sites, cannot be understood from its isolated parts. As pointed out by Fazio (2010, pp. 678–679):

"Without question, the complex reality of knowledge, motivation, beliefs, capability, and context are clearly intertwined by a complex web of dialectical interactions, which in turn concomitantly determine teachers' actions. For preservice teachers during practicum, this comprises their knowledge, beliefs, and skills in SI [*scientific inquiry*], and the associate teachers in their practicum classroom. Studying one or two elements in isolation fails to capture the dynamics and complexity of teacher actions in these settings. Dialectical approaches to study enacted practices of preservice teachers (...) may give us better insight to help design more supportive learning experiences during their practicum."

In this scenario, although, hands-on experiments are usually assumed as consistent underpinnings for ITE, they have been uncritically appropriated and in the daily life of

Science education, little room is left for understanding the actual role of hands-on experiments in ITE. Hands-on experiments are commonly used only due to its emotional appeal. Nevertheless, they hide a number of valuable elements for scientific understanding, such as philosophical issues, procedures and scientific methods, etc.

This study focuses on critically evaluating the uses of hands-on experiments in Practicum, particularly, we aim at examining critically the major challenges that student teachers face in implementing such approach as well as the possible contributions and limitations of hands-on experiments to ITE.

METHOD

This study is a yearlong research in which a cohort of 60 student teachers was tracked in 2010. In this specific teacher education program the undergraduate students must chose the teacher carrier when they get in the university. It means that they selected, in this case, physics teacher program instead of scientific programs. This division between teacher and scientific programs is a key feature of this program mainly in the formation of teacher identity. We are particularly interested in a discipline entitled 'Physics Teaching Practice' where the student teachers must spent a fourth of the practicum. Out of the 400 hours of practicum in the whole program, 100 hours are organized by and inside this discipline. During the academic year, the student teachers go to school each two weeks to perform 12 tutored activities. Indeed, this system is slightly similar to what Tobin & Llena (2010) called co-teaching. Especially in Brazilian scenario, practicum remain as an underexploited field for research (Lüdke & Boing, 2012).

The Physics Teaching Practice discipline is composed by three different moments: Firstly, the school placement itself. At school, a couple of student teachers must conduct classes shared with the regular physics teacher. They have to develop hands-on experiments (Ates & Eryilmaz, 2011; Holstermann, Grube, & Bögeholz, 2010) in which the high school students might manipulate and investigate several different physical phenomena. Along with the hands-on experiments, the student teachers have the laboratory protocols or guidelines. Even though the focus of the study is on the lab guidelines, we are not going further in the specificities of the hands-on experiments. Secondly, the student teachers have support to prepare and plan the experiments, contents and action for the class they have to conduct. One week before going to school, they spent two hours in the 'pedagogical laboratory' in order to understand and eventually make small changes in the lab guidelines. Thirdly, the student teachers take part in a class with whole cohort one week after the practicum. In this class, they foreground their experiences, problems and reflections bringing a great variety of elements for discussion. All data we will present in this article was gathered in these classes.

Over two weeks the student teachers pass through all the three moments, practicum, planning and classes. This movement is pivotal in the course because the student teachers' concrete experiences work as the content for further discussions. The retro-feeding system interconnect the planning-execution-reflection. All this moments are not well bounded and the connections are not unilateral, though. Many different demands from school, teachers and university make the connections between this tree moments much more complex and turbulent.

This is a yearlong ethnographic research (Douglas, 2011) conducted in 2010 with multiple data sources. We examine the Practicum activities which aims at articulating the specific content matter – in this case Physics, pedagogical theory provided mainly by the Faculty of Education, and the practice performed at school. As we said, we worked with a cohort of 60 student teachers and 5 people in the support team – university professor, two teacher educators and two assistants. The student teachers are supposed to develop 12 hands-on experiments over the year in middle and high schools. Besides the Practicum, they have a weekly workshop for planning the experiment and a weekly class discussion with all student teachers. The discussion classes are an important moment in supervision and supporting, great part of our data stems from the video record of this moment in which student teachers present their results, feedback from tutor teacher, and even fears and challenges.

Besides the field notes, we have videotaped the class, preparation workshops and support group meetings. We also interviewed all support group and 9 student teachers and we used the weekly written reports, questionnaires and documents produced within the course. All the participants assigned the research agreement accepting taking part in the study. Data was clustered and coded using the qualitative analysis software NVIVO 8. This wide range of data underpins our broad view on the course. Furthermore, thematic content analysis was done and all data was coded using a hybrid system of theory-driven and data-driven categories. (Edwards & Protheroe, 2004).

A large amount of data was gather using school ethnographic approach. Besides the field notes, written reports, interviews and documents, videotapes was collected. Over 2010, we videotaped 14 discussion classes and during the classes, the first author took part as assistant of the Professor, intervening and making comments.

With regard to topic discussion over the year, we split it in three parts. First, in the beginning of the year the discussion was centered on specific content – physics. Second, from April to June, student teachers experiences and problems in school. That is the period which we developed the analyses. Third, in end the discussion shifted to solution and new proposes for the coming year.

We developed the analyses in two level. At the first level, we will examine a problematic situation in practicum reported by a student teacher, Frank. He describes with vivid details what happened in previous week in the practicum. At the second level we examined how, some classes later, student teachers discuss and reflect on the problematic situations described previously. Thus, this discussion brings a sort of elements that go deep in understanding the lab guidelines uses.

One camera fixed in the corner was used and the transcription was made in Portuguese than translated into English. The number used to mark each excerpt refers to the original mark of turns. Here we will use fictional names in order to preserve personal identities. All participants accepted to take part in this research in the beginning of the year by signing an agreement term.

THEORETICAL FRAMEWORK

Practicum combined with hands-on experiments is certainly a complex issue, which requires a framework able to deal with dynamic, complex and multi-level objects. In this scenario, cultural-historical activity theory (CHAT) is particularly valuable. Based on Vygotsky's works, Engeström (1987; see also Engeström & Sannino, 2010) consolidates a useful theoretical lens for education and especially for collaborative learning and development.

Briefly, three points might express CHAT’s underpins: Firstly, the human activity is object-driven. Practitioners organize themselves to change the objective world (e.g. producing instruments and goods). Within the object, human activity effectively finds its motive. In the case of practicum, student teachers find a multifaceted object, at the same time they should learn how to teach and should teach something – specific Physics concept. In the same action, they shall accomplish a university task and be sensitive to students and school demands. Secondly, cultural artefacts mediate human action. In order to change the surrounding world human being makes use of a variety of tools. For educational activity one may list a large number of items that help teachers or student teachers to carry out instruction, it runs from textbooks, blackboard, computer, low-cost materials to concepts and analytical diagrams. Finally, the human activity exists only as a system. Human activity in the always interconnected with others, which might share some aspects – essentially its objects. For instance, all sort of activities within school, university and community necessarily supports the Practicum as an activity. Even the simplest activity inside school may hold a relevant factor for Science student teachers learning.

Therefore, the research focus is not on isolated subjects and its thoughts. The research seeks the mutual transformation of subject and object. Second, this relation subject-object is mediated by culture. It is not a direct relation, though, in order to transform the surrounding world, humankind produces, appropriates and uses the culture to do so (see Cole, 1998).

Leont'ev (2009) proposes that human activity is composed by many and different actions and subsequently each action might be composed by many operations. Such a complex organization of activity structure tell us that even a single action might be rooted in a complex net of operations. Hence, the researcher have to insert human praxis into a broad context in order to make sense of all sort of actions. The permanent interplay between activity, actions and operations plays a significant role in cultural historical activity theory. It help us to understand the development of a concrete activity through time and various levels. According to Leont'ev (2009, p. 102):

"Actions and operations have various origins, various dynamics, and various fates. Their genesis lies in the relationships of exchange of activities; every operation, however, is the result of a transformation of action that takes place as a result of its inclusion in another action and its subsequent 'technization.'"

Furthermore, the complexity of activity organization must be reflected in the mediating means, vice-versa. Learning may be translated, at least to some extent, in how one can master cultural artefacts employing toward specific goals (Wertsch, 2007). Instead of stressing the difference made by Vygotsky (1978) on material and linguistic mediation, we adopt the definition proposed by Cole (1998, p. 117; see also Ilyenkov, 1977) in which *cultural artefact are both material and ideal*. "By virtue of the changes wrought in the process of their creation and use, artifact are simultaneously ideal (conceptual) and *material*." (emphasis in the original)

RESULTS AND DISCUSSION

On the one hand, hands-on experiments are rich and highly complicated tasks for novice teachers demanding extra attention throughout practice. Part of the student teachers still are attending basic Physics classes. On the other hand, as most tutor teachers are unfamiliar with experimental approach, it is also a novel element for most tutor teachers; it means that those who are supposed to support and provide guidance are learners as well. Hence, tutors support might be limited; it is, indeed, a situation when ITE encounters in-service teacher education. It is, above all, an opportunity for university and schools to co-generate mechanisms to support tutor teachers in their daily work. Since teachers educators' main object is the student teachers learning. Thus, they are unlikely to be completely aware on tutor teacher's needs.

Disciplinary knowledge and teaching

Hands-on experiments demand from student teachers an accurate, deep and solid disciplinary knowledge. Whereas it is the strength of this approach, it also shifts student teachers' focus mostly toward disciplinary aspects leaving pedagogical aspects aside. As the practice - school based tasks - is getting earlier in the ITE program, students teachers have to face the Practicum without going deeper in the Physics content of those experiments. On one hand, commonly in the data the discussions about Electromagnetism indicate a poor appropriation of the Physics behind the phenomena. On the other hand, the experiments in Thermodynamics turn out to be far more complex to carry out. Both topics, Electromagnetism and

Thermodynamics1, show up as an extra challenge to appropriate the disciplinary knowledge while develop teaching paths to approach the hands-on experiments. Such aspect of *teaching while learning* is seems overlooked for those how claim an earlier practice insertion in the ITE program.

In terms of Activity Theory, it represents a two overlapping layers object: the first is to study, master and appropriate the disciplinary content, ultimately it means understand the Physics that are at stake; the second is the specific pedagogical path developed to carry out the teaching-learning process in the classroom with the concrete students. In the teachers' education research literature, it is conceptualized as pedagogical content knowledge (PCK) (see Sperandeo-Mineo, Fazio, & Tarantino, 2005). These two layers implies slightly different activities, which are merged in the case of Practicum, therefore, might be characterized as a *hybrid activity*.

University and school tasks

Student teachers commitment is commonly centered on university task. For example, the main concern expressed in the written reports were in fulfilling the lab guidelines and not in students learning. Therefore, our finds indicate that commitment with university task were brought to the foreground and even the student teacher own learning were left out of reflection as the university task and evaluation was the core of the process.

Although this issue of what activity the student teachers are actually engaged seem, at first glance, only an institutional or formal matter, it has practical implications in the development of Practicum and in how students teachers, school students and teachers make sense out of this concrete activity. For instance during the evaluation of their own work and performance at Practicum student teacher report the successful Practicum those in which they could go over the whole lab guideline and finish the hands-on experiment in time. The students' learning were barely mentioned as something relevant for a good or successful Practicum. In other words, the student teachers are constantly replaying the university demands while placing the school and students demands as secondary.

Even though we might label this as a hybrid activity born from the university-school encounter, a visible hierarchy put the university over school. Although we are not going into detail, it is important to acknowledge that this relation between university and school is historically built and reflect in the particular partnerships. It reflect indirectly in the development of all hand-on experiments selected for the Practicum. The wider historical and hierarchical relation between the university and the school inherently affects the accomplishment and assessment.

Moreover, in the cases studied, the nature of science and its related topics remain untouched throughout Practicum. It also indicates that more time is needed in preparation with student teachers and tutors for open up the philosophical implications of hands-on approach. Often the naive realism is taken as the philosophical ground for teaching, assuming the general level of observation as the sole source for scientific development.

Furthermore, as the research results indicate, if taken uncritically, the very same features of hands-on approach employed by novice teachers might turn out to be a weakness. To sum up, we agree with the current literature about the benefits of hands-on approach in Science

1Especially in the case of Thermodynamics, the student teacher should manage the students using water and fire during the lesson, what is currently an uncommon practice in public schools.

classrooms. Nevertheless, it also presented as complex and quite demanding for student teachers, who needs even more support and guidance in the Practicum.

REFERENCES

Ates, O., & Eryilmaz, A. (2011). Effectiveness of Hands-on and Minds-on Activities on Students' Achievement and Attitudes towards Physics. *Asia-Pacific Forum on Science Learning and Teaching*, 12(1). Retrieved from http://www.eric.ed.gov/ERICWebPortal/detail?accno=EJ937639

Cole, M. (1998). *Cultural psychology: A once and future discipline*. Belknap Press.

Douglas, A. S. (2011). Learning on the Job: A Cultural Historical Activity Theory Approach to Initial Teacher Education across Four Secondary School Subject Departments. *Ethnography and Education*, 6(2), 195–211.

Edwards, A., & Protheroe, L. (2004). Teaching by proxy: understanding how mentors are positioned in partnerships, *Oxford Review of Education*, 30(2), 2004, 183–197.

Engeström, Y. (1987). *Learning by expanding: An activity-theoretical approach to developmental research*. Helsinki: Orienta-Konsultit.

Engeström, Y., & Sannino, A. (2010). Studies of expansive learning: Foundations, findings and future challenges. *Educational Research Review*, 5(1), 1–24.

Fazio, X., Melville, W., & Bartley, A. (2010). The Problematic Nature of the Practicum: A Key Determinant of Pre-service Teachers' Emerging Inquiry-Based Science Practices. *Journal of Science Teacher Education*, 21(6), 665–681. http://doi.org/10.1007/s10972-010-9209-9

Holstermann, N., Grube, D., & Bögeholz, S. (2010). Hands-on Activities and Their Influence on Students' Interest. *Research in Science Education*, 40(5), 743–757. http://doi.org/10.1007/s11165-009-9142-0

Ilyenkov, E. V. (1977). *The concept of Ideal. In Philosophy in the USSR: Problems of dialectical materialism*. Moscou: Progress.

Leontyev, A. N. (2009). *Activity and Consciousness*. Pacifica: Marxists Internet Archive.

Lüdke, M., & Boing, L. A. (2012). Do trabalho à formação de professores. *Cadernos de Pesquisa*, 42(146), 428–451. http://doi.org/10.1590/S0100-15742012000200007

Sperandeo-Mineo, R. M., Fazio, C., & Tarantino, G. (2005). Pedagogical Content Knowledge Development and Pre-Service Physics Teacher Education: A Case Study. *Research in Science Education*, 36(3), 235–268. http://doi.org/10.1007/s11165-005-9004-3

Tobin, K., & Llena, R. (2010). *Producing and maintaining culturally adaptive teaching and learning of science in urban schools* (Vol. 1). London: Springer.

Vygotsky, L. S. (1978). *Mind in Society: The Development of Higher Psychological Processes*. Harvard University Press.

Wertsch, J. V. (2007). *Mediation. In The Cambridge companion to Vygotsky* (pp. 178–192). Cambridge: Cambridge University Press.

CONTRIBUTIONS OF A PROGRAM OF TEACHING TRAINING FOR THE PCK

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Abstract: Researchers have advocated the professionalization of teaching profession, being the construction of a knowledge base for teaching one of the necessary steps. One of these researchers include Shulman (1986, 1987), who proposed the pedagogical content knowledge (PCK) that is a specific knowledge of the teacher. In this perspective of professionalization, the Brazilian government created the Institutional Program of Teaching Training Scholarship (PIBID), a program aimed mainly for the teacher under-formation, which has as one of its main objectives the enhancement of teaching activity. This study aims to analyze the contributions of the PIBID development and pedagogical content knowledge mobilization (PCK) pre-service teachers from a University. The program occurred into three stages: presentation of the participants to the playful, classroom observations and preparation of a game. Collect data in all three steps by means of audiovisual records and written and oral reports of the students. The data were subjected to content analysis (Bardin, 2011), using as categories the domains of knowledge developed by Rollnick et al. (2008). Through this work, it was possible to observe the incentive and/or mobilization of all fields of knowledge, especially knowledge of pedagogy (educational theories and field administration), the context (physical space from school) and students (previous knowledge). We conclude that the PIBID offers a climate favourable to reflections and discussions about topics related to construction of the PCK, either developing some knowledge of theoretical form or when the student mobilizes knowledge to perform a particular activity.

Keywords: Pedagogical content knowledge; pre-service teacher; PIBID

INTRODUCTION

Shulman (1986, 1987) defends the teaching as a profession, and he acknowledges that the professor has a set of basic knowledge to exert their teaching activities. The author proposes seven knowledges, highlighting the pedagogical content knowledge (PCK), which includes "the most powerful analogies, illustrations, examples, explanations, and demonstrations" (1986, p. 9).

From the original definition, several researchers have proposed adaptations, among which we highlight the work of Rollnick et al. (2008). The authors propose four areas of fundamental knowledge for teaching: subject matter, general pedagogical, students and context. For the authors, the PCK is like an amalgam of these four areas, which when combined, generate observable products in the classroom, which are called manifestations. The authors propose four manifestations: subject matter representations, which refers to the ability to produce representations, analogies and metaphors effective; curricular saliency, corresponding to the emphasis in the teaching learning process; assessment, demonstration involving activities to evaluate student learning; and topic-specific instructional strategies, which are related to the mobilization and organization of resources to carry out a task or explanation related to specific content. Thus, such correlates the domains of knowledge base with the observable manifestations in the classroom.

In recent years, teachers' initial formation has received attention from researchers, who see in this field the possibility to identify and clarify the development of PCK (Nilsson & Loughran, 2012). It is in this context that we have developed our study, when we investigate a program instituted in Brazil aimed to undergraduate students: the Institutional Program of initiation into Teaching (PIBID, from Portuguese Programa Institucional de Bolsa de Iniciação à Docência). This program aims to raise the quality of initial teacher training in undergraduate courses and enter pre-service teachers in daily life of public high schools. Research have been developed in order to verify the PIBID efficiency for teacher training (Silva, Alvim, & Costa, 2013; Silva, Miranda, & Alvim, 2014), however, only one work under the PIBID that brings integration content-pedagogy and the PCK was found (Sa & Garritz, 2014).

Therefore, in this study we aimed to understand how the PIBID, subproject Chemistry/UFABC, contributed to the development and mobilization of knowledge base for teaching a group of students participating in the program. In this research, we used to prospect the idea of knowledge base and pedagogical content knowledge proposed by Shulman (1986, 1987) and adapted by Rollnick et al. (2008).

CONTEXT OF THE RESEARCH

A subproject of PIBID consists of: (a) area coordinator, university professor involved in the various areas of knowledge (chemistry, in our case), they will play the role of guide and direct supervisors and undergraduate students of the area; (b) supervisors, public school teachers accompanying the learning and performance of PIBID students in schools; (c) pre-service teachers (PST), undergraduate students in training.

The subproject PIBID - Chemistry/UFABC is coordinated by Professor Maria (fictitious name). She has undergraduate degree in chemistry by University of São Paulo (USP) and master and doctor in Chemistry Teaching from the same institution. The PIBID / Chemistry subproject has works in two state high schools, being one supervised by teacher Erick and other by Professor Douglas (both fictitious name). Both have undergraduate degree in chemistry.

The PIBID's proposal was to development one game that could be applicable in high schools. The work can be divided into three steps: presentation of the games to the PST; observations in the school field; and preparation of the game.

The first phase was the presentation to the playful, with the participation of professor-coordinator, teachers-supervisors and PST. Its main objective was to introduce the concept of playfulness to PST and introduce them to present games in the literature for chemistry education (have been played eight games, involving various contents: nomenclature of organic functions, periodic table, and atomic model, among others). In all, eight meetings were dedicated to this step.

The second phase happened at school in which the teacher-supervisor ministered class, and was to attend classes and assist if necessary and check the school's physical space (laboratories, libraries, classrooms). The main objective of this time was that the PST investigate the students in order to observe its deficiencies in content and behavior in the classroom. This research was intended to help them choose a game for application in the classroom. The observations took place from August to October 2014.

In the third phase, the students would fabricate the predetermined game. Unlike previous times, wherein they had a more theoretical, in which the main activity of the PST was to play and to know the game, and watch the students, this time had a more practical nature, in which the main activity of the students was to create the game . Through discussions at meetings and observations in the field, PST should choose a certain game to classes which were responsible and make the necessary modifications, according to the profile of the class - seen content, profile of students, school structure, among others.

METHODS

A qualitative approach has been adopted in this research and it was developed as a case study (Bogdan & Biklein, 1994), in which a group of six PST (Auri, Babi, Caio, Dora, Elis, Fred, fictional names), who attended the PIBID – Chemistry/UFABC, was monitored. None of the PST had any previous classroom teaching experience and only two had studied, or were studying, pedagogical disciplines.

Seeking to gather information on the case in detail, we used as data collection instrument: audiovisual recordings of PIBID meetings; and analysis of materials prepared by students during participation in PIBID. In Table 1 the collected data is listed.

Table 1: Data collected in each step of the PIBID

Step	*Data collected*
Presentation of the games to the PST	Audiovisual record of the meetings in which the games were presented;
Observations in the school field	Written reports (field notes) and oral (during meetings of the PIBID) produced by students;
Preparation of the game	Written reports (issues produced) and oral (during meetings of the PIBID) produced by the students.

The data analysis began with the transcription of meetings and classes. The data obtained through the transcript of records of meetings and applications already transcribed together with the data obtained through the CoRe analysis and document analysis were triangulated (Carvalho, 2011), converging aspects in common. Subsequently, the results of the triangulation of the data was subjected to content analysis by categorical analysis (Bardin, 2011, p. 147).

RESULTS

Presentation of the games to the PST

Initially, it was revealed the preconceptions that PST have about recreational activities:

> *It would be a different way of learning. A more formal way, you'll find it harder to learn. With the play activity, you will have a higher yield. I had such an experience as that in high school*. (Caio, first meeting, translated from Portuguese).
>
> *The playful activity is something different, different from conventional*. (Elis, first meeting, translated from Portuguese).

Before being presented to the games, PST could not understand the idea that it was possible to combine game with chemistry teaching:

I've never seen, particularly during high school, these types of games in chemistry. (Babi, second meeting, before playing, translated from Portuguese).

This first step also allowed the PST to mobilize their knowledge of chemistry. Following, we will list some episodes that took place during the meetings, in order to exemplify the expressed knowledge.

Table 2: Demonstration of knowledge of the chemical content.

Episode	*Event*
1 – Amida function	During the application of the games, it was asked to Dora if the organic function possessed by another player was an amide function, and Dora said she did not know what an amide function was.
2 – What is matter?	During the application of the games, one PST group should answer the question "What is matter? ", and the group answered: the matter is a group of atoms that can be the same or different among them, which has mechanical, optical, electrical, physical and chemical properties.
3 - Electrons	During the application of the games, one PST group should confirm the truth of the following statement: "in the model of Thompson, the number of protons equals the number of electrons". The group considered a false statement.

Observations in the school field

That was the first time that the PST observed a classroom from the perspective of a teacher. During this period the PST took notes on students (specifically), classes (in general) and the school's physical space:

The student Jon (not his real name) is more isolated, but interested in class. Search why. (Caio, field notes, translated from Portuguese).

The students in the classroom always talk a lot even while doing the exercises. Over time the students started to get more involved. (Auri, field notes, translated from Portuguese).

Agitated and talking students during the roll calling. Perhaps it was caused by the absence of classes during the day. (Babi, field notes, translated from Portuguese).

The principal was interested [in a lab proposal] and asked a shopping list with what we would need. The laboratory is well equipped. (Fred, field notes, translated from Portuguese).

Preparation of the game

Through discussions in presentation meetings and field observations, the PST should choose a certain game to the classes which they were responsible and make the necessary modifications. The PST decided to elaborate just a game and adapt it. So, it would be applicable in all monitored groups. The main reasons for the choice of the game selected were easy administration in the classroom and approach the various contents:

> *We can resume the subjects they already have seen. One aspect of revision to them*. (Caio, 15th meeting, translated from Portuguese).

> *We do not have much experience in how to deal with them. It would be simpler with this game (Pass or Repass game of chemistry).* (Caio, 15th meeting, translated from Portuguese).

> *Needs a lot of teacher attention [...] this is not possible in a room with 40 students.* (Auri, to justify not choosing another game, 15th meeting, translated from Portuguese)

We also noticed some chemicals errors in some questions developed by the PST. Babi, for example, responsible for preparing questions about inorganic functions, states that salts do not release the hydronium and hydroxyl ions:

2) What is the anion and the cation that are not produced by salts?
a) Na+ and Cl-
b) H+ and OH- (Correct answer)
c) K+ and O2-

Figure 1: Question developed by Babi (translated from Portuguese)

DISCUSSION AND CONCLUSIONS

Over the results and discussion, we will basis our discussion on two topics: knowledge stimulated, that is, knowledge that were stimulated in PST by the activities proposed by the PIBID; and knowledge mobilized, that is, knowledge that PST expressed during the activities. We emphasize that a knowledge stimulated by the PIBID activities does not necessarily reflect on a development of knowledge on the part of the PST, but we believe that the stimulus is a first step towards such.

It was possible to perceive stimuli and / or manifestation of all knowledge in all stages of the subproject, but we will present here only the main knowledge of each step.

General Pedagogical Knowledge (GPK)

In the GPK we included the categories: educational theories, teaching approaches and the knowledge regarding the administration of the classroom (Rollnick, 2008; Grossman, 1990).

We believe that the first two were stimulated throughout the sub-project. Initially unaware of the PST aspects of playfulness, especially regarding the use of games for chemistry teaching.

However, throughout the project development, we have acquired knowledge and experience on such an approach.

It is noticed that the third one was mobilized when PST justified the choice of the game for its ease of application and control of the classroom. What was their first experience, PST felt fearful about the game application, so they chose the game they believed to be better to maintain control and discipline in the classroom.

Context Knowledge (CoK)

In this field Rollnick et al. (2008) include all the contextual variables that can influence a teaching situation, such as the class size, the viability of resources and other school spaces. The main point of stimulation of this knowledge it was during the observation in the field and are recording the physical school environment. Some of the PST visited thoroughly the school science lab, noting the glassworks and reagents that are present in the laboratory, aiming at the future, the development of a practical class.

It was also observed that the PST mobilized this knowledge when choosing the game to be applied because they justify not choosing other games based on these criteria: certain games needed tools that the school did not have; other sets were the most suitable groups with a lower number of students.

Students Knowledge (KoS)

Here we include the students' prior knowledge, your skills and interests (Rollnick, 2008). The main point of stimulation of this knowledge it was during the observation in the field, in which PST took notes related to the maturity of the students, some shortcomings in the chemical content and base content (such as arithmetic) and the aspirations of some students.

The PST mobilized this knowledge when choosing the games, when selecting a game that best fitting in students' profile, and in the preparation of the game, trying to propose issues at a more appropriate level students

Subject Matter Knowledge (SMK)

In the SMK three categories of knowledge are included: content (facts and concepts), substantive structures (explanatory structures or paradigms) and syntactic (methods and processes by which new knowledge is generated) (Grossman, 1990). The game elaborated by the PST were just facts and concepts, being possible to observe mainly mobilization of knowledge of the content.

This was a difficult knowledge to be examined, since it is specific to a content, but PST knew and developed games with different content. Therefore, we set out to analyze the "chemistry knowledge" of PST in general. From the first step we could see some flaws in basic knowledge of chemistry, such as organic function and structure of matter. In game development stage students also developed some wrong questions.

However, we emphasize that the PST also expressed to know some contents, which were not shown here because we believe that the failures here listed are more important and need more attention than the contents that they showed to know, to be deficiencies in basic content of chemical and basic content for chemistry teaching for years in high school.

Pedagogical Content Knowledge (PCK)

PCK is a specific knowledge of a teacher and it is a tacit knowledge of strategies used for that a specific content could be understood by a student (Shulman, 1986). PCK can manifested four categories: representations, instructional strategies, curricular saliency and assessment (Rollnick, 2008).

It was possible to realize the mobilization in the curricular projection category: some PSTs justified that drew up the questions in order to help students in the college entrance exams; other PSTs justified that they drafted based on what they believed to be the most appropriate level for the students. Another category was developed to outline specific instructional strategies, once PSTs had contact with several sets of the most varied topics.

Conclusions

Generally, the knowledge presented by the PST have many deficiencies, such as conceptual flaws in SMK and unsuitability to games (as the courses were in a different context it was expected that PST had prepared more specific games for each class, and not a game for all classes). Regarding the SMK, we believe that it must be given more importance to this area in particular: during the meetings was revealed that the PST had flaws in their SMK; and on preparing the questions the PST have developed questions with misconceptions. Thus, it is essential that more time have to be invested to stimulation of this area of knowledge.

However, we emphasize that this was the first experience of PST as teachers and only two them attended educational courses at the time the data were collected. Due to the great lack of experience, both practically and theoretically, it is expected little reliance on the knowledge base. More important than highlight the lack of PST, it is to highlight the knowledge that they were able to mobilize and develop over the PIBID. It was possible to see the development and / or mobilization of all fields of knowledge, particularly the GPK.

We, therefore, conclude that the PIBID provides a favorable environment for reflections and discussions on topics related to building the knowledge base for teaching, however, it is necessary for the SMK get out of the background and assume a more important role during the development of activities.

REFERENCES

Bardin, L. (2011). *Análise de conteúdo*. São Paulo: Martins Fontes.

Bogdan, R., & Biklein, S. (1994). *Investivação qualitativa em educação*. Porto: Porto Editora.

Carvalho, A. M. P. (2011) Uma metodologia de pesquisa para estudar os processos de ensino e aprendizagem em salas de aula. In: F. M. T. Santos & I. M. Greca (Eds.), *A pesquisa em ensino de ciências no Brasil e suas metodologias* (pp. 13-48). Ijuí: Editora Unijuí.

Grossman, P. L. (1990). *The Making of a Teacher: knowledge and Teacher Education*. New Yoker: Teachers College.

Nilsson, P., & Loughran, J. (2012). Exploring the Development of Pre-Service Science Elementary Teachers' Pedagogical Content Knowledge. *Journal of Science Teacher Education*, 23(7), 699–721.

Rollnick, M., Bennett, J., Rhemtula, M., Dharsey, N., & Ndlovu, T. (2008). The place of subject matter knowledge in pedagogical content knowledge: A case study of South African teachers teaching the amount of substance and chemical equilibrium. *International Journal of Science Education*, 30(10), 1365–1387.

Sá, L. P., & Garritz, A. (2014) O conhecimento pedagogico da "natureza da matéria" de bolsistas brasileiros participantes de um programa de iniciação à docência. *Educación Química*, 25 (3), 363–379.

Silva, M. P., Alvim, M. H., & Costa, L. C. (2013) *A formação docente em contexto colaborativo no PIBID/UFABC*. Jundiaí: Paco Editorial.

Silva, M. P., Miranda, M. A. G. C. M., & Alvim, M. H. (2014) PIBID/UFABC e o Processo Ensino-Aprendizagem em Ciências e Matemática: coletânea de artigos. Jundiaí: Paco Editorial.

Shulman, L. S. (1986). Those Who Understand: Knowledge Growth in Teaching. *Educational Researcher*, 15(2), 4–14.

Shulman, L. S. (1987). Knowledge and teaching: Foundations of the new reform. Havard Educational Review, 57(1), 1–22.

MODELING IN ELEMENTARY SCHOOL PRE-SERVICE TEACHER EDUCATION: THE INFLUENCE OF TEACHING SCENARIOS

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Abstract: In this research study we analyse the modeling practices of pre-service primary school teachers when participating in small group, laboratory-based discussions to model scientific phenomena. The context is a science education course with a twofold aim: 1. improve their modeling abilities of expression, use, analysis and revision of models and 2. the construction of adequate versions of key conceptual models related with core ideas in science, such as the particulate model of matter.

In our research, we select and analyse critical video-episodes of students' modeling efforts in order to characterize potentially rich or empowering teaching scenarios (activity contexts) where the aforementioned modeling practices take place. Our analysis describes different aspects of the activity context, such as the theoretically or empirically-grounded inputs from diverse agents and tools, in order to characterize which aspects are more critical in supporting or limiting fruitful modeling activity. This latter is characterized at both the level of practices (rich modeling patterns) and the level of ideas (emergence of potential aspects in students' models that act as step-stones in the construction of the key conceptual model).

Preliminary results show the non-linear pathway that students' models follow along the modeling activity, and signal the importance and relation between certain teaching scenarios (in particular, demands for expression of the model in drawing) with high level modeling practices (such as analyzing your model) in the evolution of students' models. Results also point out the difficulty in self-guided scenarios to take benefit of the rich modeling activity taking place, and not surprisingly show the influence of the teaching situation in terms of teaching design (such as well-structured demands of expression of models or final joint revision of their models) in favoring that students take advantage of potential events for the construction of an adequate version of the key conceptual model.

Keywords: Modeling / models, pre-service teacher education, primary/elementary school

INTRODUCTION

Viewing science learning as participation in the practices of science is a framework gaining momentum at both the science education research literature and recent policy documents (NRC, 2007). This framework proposes an underlying structure for scientific activity that is relevant both in science and in school science. Scientific activity is viewed as the discursive and social activity of developing explanations, carrying out investigations and evaluating and arguing with evidence (Osborne, 2014). This refers to the interrelated scientific practices of modeling, inquiry and argumentation that should, therefore, become central in school science

Why introducing scientific practices in the science classroom can be justified both in terms of learning potential and epistemic adequacy *"to overcome traditional methods that ignore both the epistemic frameworks used when developing and evaluating scientific knowledge, and the social processes and contexts that shape how knowledge is created, communicated, represented, and argued"* (Grandy & Duschl, 2007, p. 144). In this sense, the origin of the idea is related with 2 different but interrelated theoretical constructs. On the one hand, the socio-cultural & historical perspective of learning, in which learning is seen as participation in the social activities and pursues of communities (Lave & Wenger, 1991). On the other, the epistemic perspective of scientific knowledge, related with the growing recognition that epistemic knowledge is part of scientific knowledge and it is important for students (Osborne, 2014). Both ideas combined claim for a teaching and learning that allow students to participate in "school science" activities that are socially-embedded and both discursive and cognitive in nature, which are also coherent with or analogous to (but not the same as) those of real science. In our own understanding, teaching science within the scientific practice framework implies making students' experience what makes science different from other ways of knowing in a way that facilitates their learning.

These practices, however, are not taking place in schools. As some authors have pointed out, in most science classrooms the focus on the products rather than the processes of science is prevalent (Duschl & Grandy, 2008). When referring to the elementary school, we face the dichotomy between either a traditional transmissive teaching mostly textbook-centred or a supposedly innovative one based on inquiry that in reality is a mere following of an stereotyped "scientific method" (Windschitl, Thompson, & Braaten, 2008). In particular, the practice of scientific modeling is rarely incorporated into educational experiences of elementary school students (Schwarz et al., 2009), sometimes because models, as abstract entities, are considered inadequate for young pupils.

However, modeling is crucial within the semantic view of science that is mostly accepted in science education, which considers that *"scientific methodology is primarily about making, testing, and using conceptual models of patterns in physical realities"* (Halloun, 2004, p. 29). Within this perspective, the aim of "epistemologically adequate" school science is to build "adequate enough" explanations of how the world works. In relation with the other scientific practices, we see models are the final aim of minds-on investigations (those that are not simplistic inquiry) and the root base of scientific argumentations (those that are not mere persuasion or argument).

Introducing the framework of scientific practices and particularly modeling in primary school is is necessarily a matter of teacher education that should start in pre-service training. For teachers to be able to involve their students in scientific practices such as modelling, they should be first able to actively and adequately engage *themselves* in such practices (Davis, 2003). However, the new framework poses great challenges for pre-service teachers (Reiser, 2013) that demand for well-designed teacher education courses. Research shows that teachers will need specific support with the practices as well as with the scientific ideas addressed by those practices (NRC, 2007). With the aim to contribute to this line of research, in this study we design and investigate a teacher education course for pre-service primary school teachers (PTs) based both on models and modeling.

In agreement with and elaborating from Schwarz and colleagues (2009), we made an attempt to operationalize the modeling practice that can be made accessible and meaningful at primary school. This is modeling as both social and personal engagement in "*sensemaking around developing ideas*" (p.637), rather than the common approach to models as communication of finalized ideas. As such, school modeling encompasses the practices of co- and self-construction and evaluation of models, which take place when engaging in the expression, use, evaluation and revision of models. Figure 1 shows our definitions of these four modeling practices.

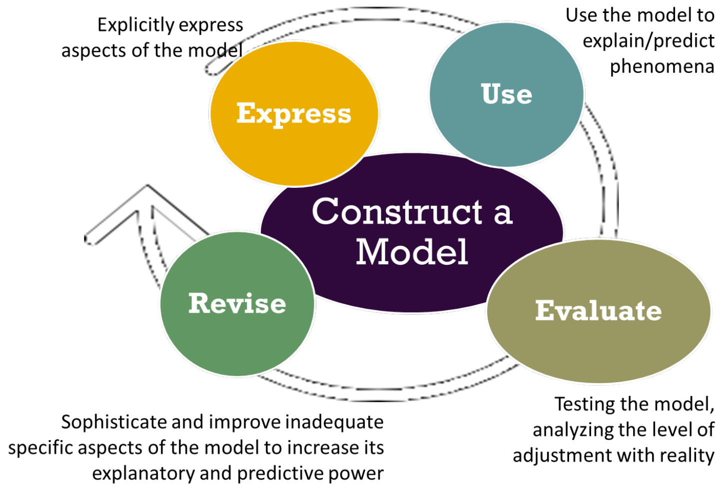


Figure 1: Modeling practices (adapted from Schwarz et al., 2009)

In addition, our view of modeling stands from the assumption that participation in scientific practices is not only for learning to engage in these practices (procedural dimension) or about these practices (epistemic dimension), but also for learning conceptual knowledge in which to frame them. This conceptual knowledge is not a set of many concepts and theories, but a small number of big (Harlen, 2010) or core ideas (NRC, 2012) that have potential to explain a lot of different phenomena and would be develop in progression along the educational path. These ideas are school-based scientific or conceptual models, such as the particulate model of matter or the model of Newtonian forces, which are considered target models in our teaching.

The teaching scenarios that provide opportunities for PTs' to engage fruitfully in the modeling practice of Figure 1 to learn the afore-mentioned school-based scientific models are those that promote interaction within a classroom culture that motivates to figure out (Reiser, 2013). A plausible context is that of small-group laboratory-based discussions where the need for an explanation arises from work on phenomena that can be interpreted with key scientific models (see Figure 2).

Figure 2: An example of small-group laboratory-based discussions of the PT's course

To organise this teaching, we have defined an instructional model consisting on 6 phases for the individual and collective construction of the school-based scientific model. These phases are elaborated from different proposals of model-based teaching and learning available in the literature (Baek, Schwarz, Chen, Hokayem, & Zhan, 2011; Hernández, Couso, & Pintó, 2015; Schwarz et al., 2009; Windschitl et al., 2008), and are described as:

- M1. Feel the need of a model (to explain or act upon a phenomena)
- M2. Express / use an initial model (think individually)

- M3. Evaluate the model (testing the model or analyse the level of adjustment of the model with reality/data from reality)
- M4. Review the model (sophisticate and improve inadequate specific aspects of the model with the help of other's ideas)
- M5. Express a final consensus model
- M6. Use the model to predict or explain new phenomena

The aim of this research is to analyze the modeling practices (MPs) and mental models (MMs) of pre-service primary teachers in the aforementioned instructional context. The idea is not only to describe what MMs are constructed or what and how MPs take place, but also to analyse the influence of aspects of the teaching scenario on both.

In concrete, our research questions are:

1. In which modeling practices do PTs engage?
2. What empirical learning progression do PTs follow regarding the target models being taught?
3. What and how teacher education scenarios support (or not)
   - An adequate range of modeling practices? (practice mastery)
   - An adequate learning progression towards the target conceptual model (content mastery)
4. Which relation exists between engagement in scientific practices and the mastery of key scientific models?

METHOD

Context

The context of this research is an existing teacher education course called "Didactics of science", part of the 3rd year of primary-school teacher education degree. The subject is compulsory and is divided into 12 sessions of 2 to 4 hours each, taking place from Sept-15th 2014 to Dec-8th 2014. The number of students enrolled in the subject was 80.

The subject has been collaboratively designed by a group of science education researchers and based on literature about primary-school teachers training (Mikeska, Anderson, & Schwarz, 2009). Its aim is to engage PTs in modelling practices focusing on inquiry and group discussions, to construct the main school scientific models in geology, physics, chemistry and biology.

Data gathering

In order to know which models and modelling practices PTs engage in, as well as the teaching scenario that influences in both, we have video and audio recorded all the course sessions. In particular, we have audio and video recorded a sample of 6 working groups while engaging in small-group discussions and doing lab work. Each small group is formed by 4 to 6 pre-service teachers. We have also collected each participant's written productions and tasks.

Data analysis

To accomplish the aim of this research, we have selected, transcribed and analysed critical video-episodes of PTs' modeling efforts, when discussing in small groups in the lab context. In a first stage of analysis we selected those video-episodes that were rich in terms of the modeling practice taking place. Then, the selected video-episodes were transcribed and analysed using a qualitative analysis software *Atlas.ti*.

We first characterized, for each unit of analysis (that could be either a sentence, an intervention or a short part of the discussion), which modeling practices emerge (use, expression, evaluation or revision of models) and the level of which ideas on the model are being discussed (emergence of potential aspects in PTs' models that act as step-stones in the construction of the key target model), identifying which pre-service teachers were involved in the modeling practice or expressed the model idea. Then, an identification, analysis and interpretation of unexpected patterns in data was made, such as shifts in the modeling practice or in the version of the model expressed.

Secondly, we identified different aspects of the teaching scenario that act as inputs in the conversation which drived or shifted the modeling activity into a new direction. These could be examples of supportive teaching (such as improvised or prepared teacher's intervention, task proposed in the lesson plan, etc.) or aspects of the activity context (such as new data obtained, peer's comments or new ideas, etc.). The teaching scenario was also characterized regarding its theoretical or empirical nature.

Table 1 shows an example of the transcript and analysis done of a video-episode of a small group of 5 PTs involved in the tasks of modeling at micro level to explain the reduction of volume when mixing alcohol and water (target model: particle model of matter). Each pre-service teacher was labeled with letter A followed by a number (i.e. A1, A2, A15…), in this case from A7 to A11. The categorization included the identification of the modeling practice taking place, the ideas or version of the target model that students' hold, and a description of the teaching scenario (supportive teaching or activity context) and its nature.

Transcription of pre-service teachers' dialogue (critical episode 6)	**Modelling activity**		**Teaching Scenario (ST/AC)**
	Modelling practices	**Models**	
Didactic situation: Demand from the teaching sequence to express the model in drawing. A7: "*I don't know…how can we draw it? Because it says that we have to draw particles of water and alcohol.*" A9: "*So, I will draw some particles A, some particles B, and the mix.*" A7: "*without saying which particles is each of them…*" A9: "*oh yes. [..] "Some big A particles, some big B particles, and when they get mixed smaller, right? Actually the mix of water and alcohol has reduced space, so the particles are smaller or they are more divided.*" A10: "*But actually, I would put some A particles, some B and in the middle some AB.*" A9: "*but would those be, equal, smaller, bigger, more divided, or…?*" A11-A10: "*they would be equal, but… I mean the double of one*" A7: "*Okay, but then why they occupy less space?*" A9: "*then they will occupy more space*" A11: "*so..*" A7: "*yes, there should be something that…*" A10: "*oh, of course*" A11: "*right, but not half of it!*" A9: "*right something more like… it loses a 10%, right*?" A7: "*we are talking about something so small it has to be just a little bit. […] but I think that we should make clear that A is water and B is alcohol so we can expose that not mixed water is at the bottom and not mixed alcohol is at the top.*" (They start drawing their models)	Express the model (A9) Express the model (A11, A10) Analyse the model (A9, A7, A11, A10) Revise the model (A9, A7, A11)	***(M2) Particles' interaction:*** *Interaction between particles creates new particles that (are smaller and) therefore occupy less space* ***(pre-M2) Particles' interaction:*** *Interaction between particles creates new particles ~~that occupy less space~~.* ***M2* vs pre-M2*** ***(M2*) Particles' interaction:*** *Interaction between particles creates new particles that are smaller (in direct proportion to the observed changed of volume) and occupy less space*	Empirical input – taking into account previous observations (A9) (final volume is less than initial) ---------- Theoretical input – peers' alternative model (expression of a model that doesn't explain data) (A11, A10) Theoretical input – new ideas from the model (considering proportionality) (A11)

Table 1: Analysis of the transcript of a video-episode in terms of modeling activity.

To analyze the influence that the modeling practices and models emerging in the small-group discussion had on each participant's learning, we also analysed their individual written and graphical productions at the end of the teaching, identifying which version of the model was expressed in their final productions. Table 2 shows an example of PTs' final productions regarding the mixture of alcohol and water and the version of the particle model of matter shown by each of them (M1, M2, etc.).

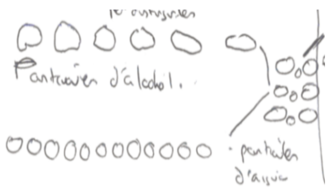
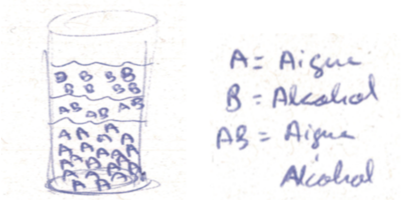
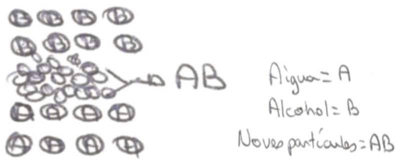
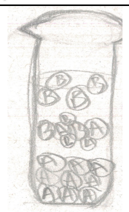
A7		*The volume is less because particles from one and the other material* ***interact and occupy less space****. Particles that haven't interact are the ones that make us see it mixed, water down because it is more dense, and alcohol up because it is less dense.* ***The ones that have interacted occupy the emptiness that was within the space.***	**M1** **M2**
A8		*We consider that alcohol and water molecules mix up and* ***interact****.* ***The empty spaces that fill up have a limited capacity.*** *The rest of the liquid that can not mix, where the alcohol goes up and water falls down. The mix between alcohol and water has a mixed density, and it would be in the middle of the test tube.* ***The volume is less due to the union between particles.***	**M1 *** **pre - M2**
A9		*I have thought that water particles are more dense than alcohol particles, and that when we mix them we see that* ***particles occupy less space****.* ***We deduce that there is the formation of a new particle that occupy less space.***	**M2**
A10		*We think that the particles that have been created from mixing water and alcohol* ***occupy less space that particles of each liquid separately.*** *Therefore, we miss a little bit of liquid.*	**M2**
A11		*Particles of water and alcohol interact, and* ***these new particles ocupy less volume****. The particles of water that don't get mixed remain at the bottom because it is more dense. Alcohol ones remain on the top of the tube.*	**M2**

Table 2: PTs' final individual written and graphical productions to express their model (particle model) when interpreting the reduction of volume in a water and alcohol mix.

To be able to identify possible modeling patterns and relations between characteristics of the scenarios and richness of modeling activity, we transformed and integrated the previous detailed analysis (which included the transcription of the episode or the written task) into a more visual and summarized representation tool. Figures 3 and 4 in the results' section are examples of this tool, that we have called "Modeling Graph" (MG). In these graphs, each discourse intervention of the PT's is represented as a box with the PTs' code (A1, A2…). The boxes are situated vertically regarding its modeling practice and are colored with the color of the version of the model expressed or implied in their intervention. In this sense, each version of PTs model and the underlying ideas of the model has been represented in a different color from lighter to darker to reflect the increasing complexity and adjustment towards the target model. As such, these graphs show the evolution and sequence of modeling practices taking place in students' practice (use, express, evaluate and revise) and also the evolution of the PTs' ideas on the model. In the horizontal axis, the graph also relates each intervention (characterized with a version of the model and a type of modeling practice) with the teaching scenario in which it takes place, shown in chronological order (See Figure 3 and Figure 4).

RESULTS

The results in this paper refer to two different classroom episodes where students were modelling two different models. The first one refers to a classroom episode where students are asked to explain flotability of balls made of different materials using both a model in terms of relative densities and a model in terms of the affecting forces (weight and buoyant force). The second refers to students' modelling of the particle model of matter to explain what happens in a mixture of alcohol and water, as seen in Table 1. Both situations have been selected to show different aspects of the modeling practices and model ideas of PT's, together with different characteristics of the teaching scenarios that seem to have an stronger effect on them.

Episode 1: The importance of thinking and talking the model in the lab

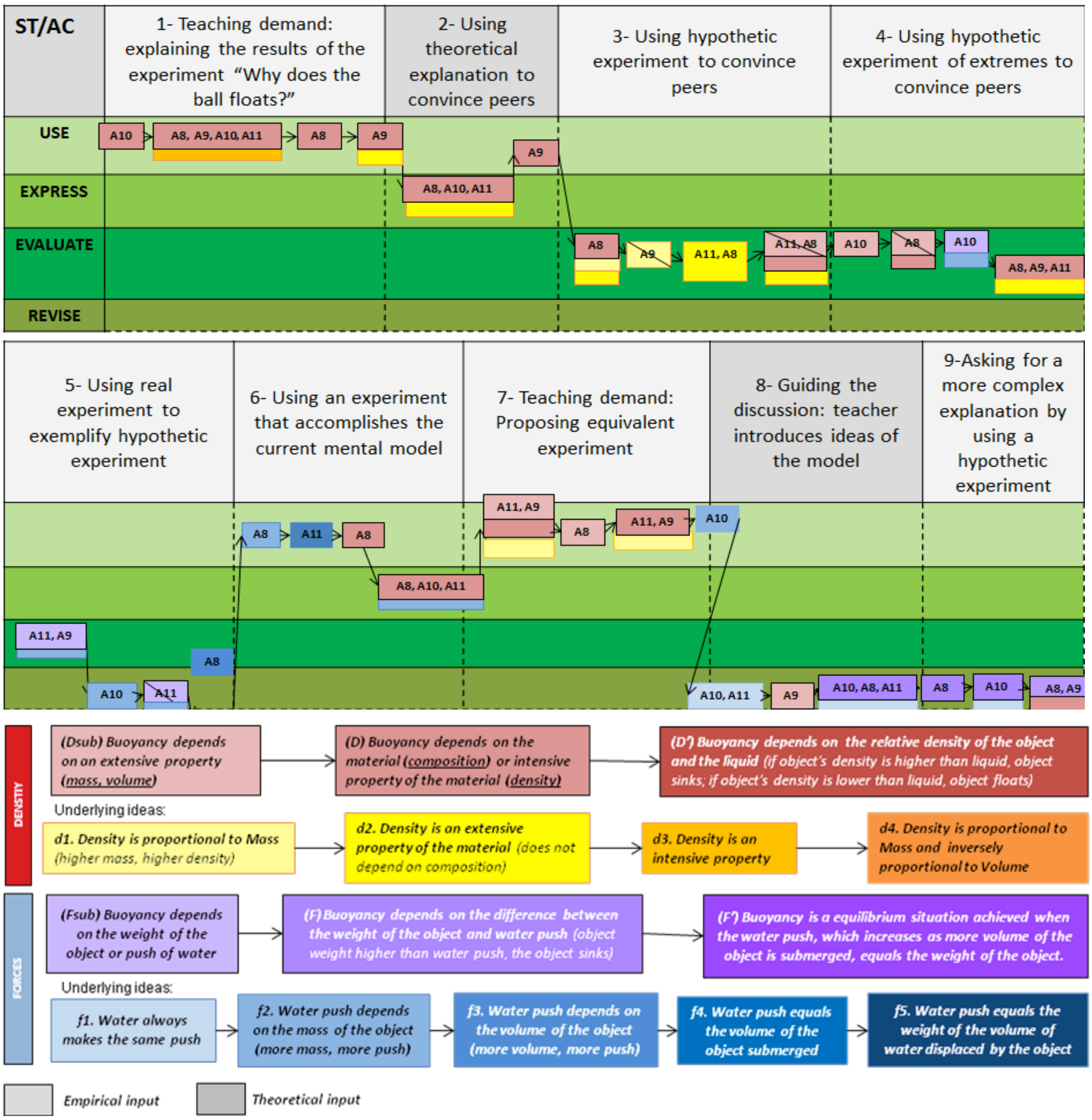


Figure 3: Representation of the sequence of PTs modeling practices and their models when discussing about which variables affect the buoyancy of objects (Mass, volume or composition) by using both a model in terms of relative densities and a model in terms of the affecting forces (weight and buoyant force). ST/AC = Supporting Teaching/ Activity Context

Episode 2: There is more learning in the activity than that emerging in the final productions

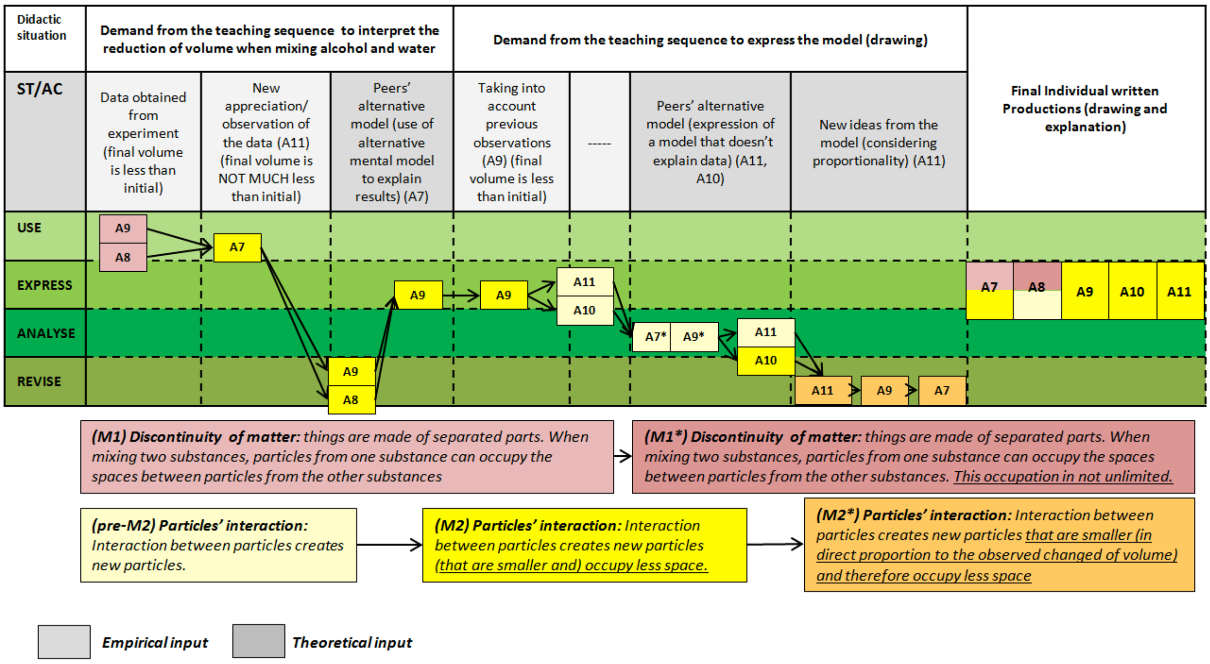


Figure 4: Representation of the sequence of PTs modeling practices and their models when discussing about the reduction of volume when mixing alcohol and water (particle model of matter). ST/AC = Supporting Teaching/ Activity Context

DISCUSSION AND CONCLUSIONS

Both selected episodes 1 and 2 (Figures 2 and 4) represent a discursive sequence of labwork group talk where all expected MPs emerge (the modeling practices use, express, evaluate and revise). They also show different students' mental models (MMs) emerging in a variety of teaching scenarios. Graph 4 also includes the models used in the final individual written productions, in the last part of the graph.

Variety and quality of modeling practices (MPs) and ideas of the model (MMs)

The results in both episodes show that engaging students in scientific practice (following the aforementioned modeling instructional sequence of 6 phases in the context of small-group labwork discussions) allowed for a diverse range of modeling practices to emerge and for the progression of pre-service teachers' models to take place.

Regarding PTs modeling practices (MPs), in both episodes all modeling practices are present, from those simpler (expression and use) to those more sophisticated (evaluation and revision). Despite the great apparent diversity of Figures 3 and 4, an emerging pattern is found. This refers to a common sequence of use-evaluate-revise the model that is similar to that proposed in the instructional design.

Regarding the PTs' ideas of the targeted models (MMs), both episodes show that there is a non-linear evolution but going back-and-fourth along the discussion from more simple to more complex ideas (See Figures 3 and 4). According to our results this fact is not necessarily problematic, as the explicit analysis and discussion of non-adequate model (such as the pre-M2 in Episode 2, Figure 4) shows crucial in allowing an step forward towards a more sophisticated model (M2*).

However, if this emerging more sophisticated ideas are or can be actually learnt is not clear. Our data shows that along the teaching activity and for different students' groups (and models) it is evidenced that many emergent more sophisticated ideas of the model are not actually discussed and get lost (for example, in Episode 1, ST/AC #6, Figure 3). More clear is even the non-appearance of M2* in the final productions of students, after the lab-work session (Figure 4 and Table 2).

There are different interpretations of why this richness in understandings that appears in the lab-work group activity gets lost. Interestingly our data seem to show that there is a lot of influence of students' portrayed self-confidence when expressing ideas, and signals the difficulty in self-guided scenarios to take benefit of the rich modeling activity taking place. In our view, one way of overcoming this problem is by modifying the teaching design to help in this area. For instance, one can argue that more modeling work with M2* (such as a demand to use it to interpret new phenomena) or a more structure demand in the final production (such as asking for a proportional representation of particles and spaces among them) could have helped in its internalization.

The analysis of PT's ideas of the model also show that key concepts play a very important role in modeling for the construction of school models. For example in Espisode 1 for the construction of a model of flotability, students engage in long discussions regarding their understanding of density or buoyant force (in yellow and blue in Figure 3, respectively). The lack of a proper understanding of these key concepts act as a main obstacle for adequate model construction and progression.

The influence of the teaching scenario

In both episodes we can also see that the teaching scenario has an impact in the sort of modeling practices taking place. This refers to both supportive teaching that is planned for promoting modeling practices and to non-planned activity contexts that emerge along students' activity.

As an example of the influence of a teaching scenario that is planned, Episode 2 (Figure 4) shows how the important practice of evaluating a model, which shows necessary for a real change in the MM of the PTs', occurs in teaching situations that explicitly ask for a graphical expression of the model, signalling the importance of this teaching demand.

As an example of non-planned but influential teaching scenario, in Episode 1 (Figure 3) it is seen how a particular activity context (in this case minds on experimental activity, such as ST/AC #3: "*use of an hypothetic experiment to convince peers*") triggers the shift from a non-evolving use of a model towards not so common and more sophisticated modeling practices, such evaluation and even revision, either directly (ST/AC #3, Figure 3) or indirectly: e.g. promoting a new real experiment equivalent to the thought one (ST/AC #5, Figure 3). This trend, which in our study is seen also in other episodes, signals the important role of students' proposed thought experiments for sophisticating their models. This is particularly relevant because it shows the importance of the discursive and cognitive activity of students' (for instance, imagining an hypothetic situation) when engaging in scientific practice, which transcends the empirical context of traditional lab-work activities.

However, despite its positive influence in the diversity and quality of the emerging modeling practices, minds on mental activity do not have a necessarily positive impact on the quality of the emerging ideas of the model or students MMs. In fact, minds-on experimental activity facilitate the emergence of new model ideas, but not necessarily good ones: for instance the idea of water push depending on the mass of the object did emerge due to the proposition of an hypothetical extreme experiment comparing cork and iron (ST/AC #4, Figure 3) despite students had real experimental data comparing cork and wood.

Finally, our results also show that, as always, there is crucial importance of teacher feedback. For example, the teacher intervention with theoretical inputs is generally associated with students' revision of the model and introduction of new ideas (for instance, Figure 3 ST/AC # 8).

As a main conclusion, our research shows that the instructional sequence followed and the selected educational context (small-group laboratory-based discussions) is a fruitful scenario for the scientific practice of modelling to take place in a rich way. When the aim is to construct student mental models that are really close to the targeted ones (as those necessary to be mastered by future science teachers), however, more needs to be done, as the richness of ideas of the model that emerge in the discussions gets partially lost. Our results also signal the importance of particular teaching scenarios in both MPs and MMs, and how theoretical ones have crucial roles in sophisticating performance both at modelling and mastery of the model level.

Finally, just to share with the reader that within a design-based research perspective we planned that the knowledge gained about particular problematic situations of construction of particular school models would be used in the future to re-design of the subject.

REFERENCES

Baek, H., Schwarz, C., Chen, J., Hokayem, H., & Zhan, L. (2011). Engaging Elementary Students in Scientific Modeling: The MoDeLS 5th Grade Approach and Findings. In M. Khine & I. Saleh (Eds.), *Dynamic Modeling: Cognitive Tool for Scientific Enquiry.*

Davis, K. S. (2003). "Change is hard": What science teachers are telling us about reform and teacher learning of innovative practices. *Science Education*, *87*(1), 3–30.

Duschl, R. A., & Grandy, R. E. (2008). *Teaching Scientific Inquiry: Recommendations for Research and Implementation*. Rotterdam, Netherlands: Sense Publishers.

Grandy, R., & Duschl, R. a. (2007). Reconsidering the Character and Role of Inquiry in School Science: Analysis of a Conference. *Science & Education*, *16*(2), 141–166.

Halloun, I. A. (2004). *Modeling theory in science education*. Dordrecht, The Netherlands: Kluwer Academic Publishers.

Harlen, W. (2010). *Principles and big ideas of science education* (p. 60). Gosport, Hants, UK.

Hernández, M. I., Couso, D., & Pintó, R. (2015). Analyzing Students' Learning Progressions Throughout a Teaching Sequence on Acoustic Properties of Materials with a Model-Based Inquiry Approach. *Journal of Science Education and Technology*, *24*(2-3), 356–377.

Lave, J., & Wenger, E. (1991). *Situated Learning: Legitimate Peripheral Participation*. Cambridge, UK: Cambridge University Press.

Mikeska, J. N., Anderson, C. W., & Schwarz, C. V. (2009). Principled reasoning about problems of practice. *Science Education*, *93*(4), 678–686.

NRC. (2007). *Taking Science to School: Learning and Teaching Science in Grades K-8*. Committee on Science Learning, Kindergarten Through Eight Grade K-8. Richard A. Duschl, Heidi A. Schweingruber, and Andrew W. Shouse, Editors. Board on Science Education, Center for Education. Division of Behavioral and Social Sciences and Education. Wash: The National Academies Press.

NRC. (2012). *A framework for K-12 Science Education. Practices, Crosscutting Concepts and Core Ideas*. Washington, D.C.: The National Academies Press.

Osborne, J. (2014). Teaching Scientific Practices: Meeting the Challenge of Change. *Journal of Science Teacher Education*, *25*(2), 177–196.

Reiser, B. J. (2013). What Professional Development Strategies Are Needed for Successful Implementation of the Next Generation Science Standards? Retrieved from http://www.k12center.org/rsc/pdf/reiser.pdf

Schwarz, C. V., Reiser, B. J., Davis, E. A., Kenyon, L., Achér, A., Fortus, D., … Krajcik, J. (2009). Developing a learning progression for scientific modeling: Making scientific modeling accessible and meaningful for learners. *Journal of Research in Science Teaching*, *46*(6), 632–654.

Windschitl, M., Thompson, J., & Braaten, M. (2008). Beyond the Scientific Method : Model-Based Inquiry as a New Paradigm of Preference for School Science Investigations. *Science Education*, *92*(5), 941–967.

PROMOTING PRE-SERVICE TEACHERS' PROFESSIONAL VISION OF INSTRUCTIONAL SUPPORT IN ELEMENTARY SCIENCE CLASSES[1]

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Abstract: Professional vision is considered a central component of teaching expertise, and it is regarded as fundamental for acting professionally and reflecting in classrooms (Sherin, 2007). Currently, various research groups are examining the question of how professional vision can be fostered in (pre-service) teacher education. For this purpose, video-based teaching/learning environments are often used in different groups and domains (Blomberg et al., 2013). In primary school science education, there is a lack of studies investigating the efficiency of such learning environments.

In the present study, a case-related, video-and-text-based programme (n = 28) has been compared to a case-related, text-only-based programme (n = 31), and to a control group without case-based learning elements (n = 35) in order to examine the promotion of undergraduate students professional vision concerning instructional support including aspects of cognitive activation and content-related structuring. To measure professional vision, a standardized video test was applied. Initial results of our study show that the group additionally trained with videos could outperform the group with the text-based programme in professional vision regarding the topic trained in both case-related programmes, whereas there were no differences between the control group and the group with the text-based programme.

Keywords: video-based learning – instructional support in science classes – professional vision

GOAL OF THE STUDY

Research in teacher training, often resorts to working with case studies in the classroom, in order to further the professional development of students (e.g. Shulman, 1992). One medium in this regard that is often used in case-based research is video (e.g. Pauli et al., 2014). Unexplained up to this point, however, is whether the use of video in relation to the use of text, which is traditionally used in case studies, brings added value for encouraging the professional development of (pre-service) teachers. Whether or not different types of media can influence learning in this respect is a topic controversially discussed in research (e.g. Clark, 1994; Kozma, 1994). Various studies (e.g. Moreno & Valdez 2007; Yadav et al. 2011; Koehler, Yadav, Phillips, & Cavazos-Kottke, 2005) that have researched the possible influence of text and/or video-based cases provide heterogeneous results that do not indicate the superiority of one of the two media.

The present study will investigate professional vision (PV) in classes as a part of the professional development of pre-service teachers. In various studies, video cases (e.g. Sherin, 2007; Stürmer et al. 2013) and video and text-based cases (Sunder, Todorova, & Möller, 2015) have already been used successfully to foster PV. As yet, however, studies are lacking that address the question of whether the work with video cases is a necessary component for success and whether they have added-value in respect to fostering PV. The present study investigates this question. To this end, the work with text-based cases and with text and video cases with regard to the fostering of pre-service teachers' PV of instructional support strategies in primary school science lessons will be compared.

PROFESSIONAL VISION OF INSTRUCTIONAL SUPPORT IN PRIMARY SCIENCE LESSONS

PV is defined as the ability to notice learning-relevant events in the classroom and – by drawing upon theory – to adequately interpret them (e.g. Sherin, 2007). At the same time, in order to focus on relevant events, observers must ignore irrelevant aspects, something that requires selective attention (e.g. Sherin 2007; Stürmer, Könings, & Seidel, 2013). In the interpretation of the perceived events, there are three subprocesses: describing, explaining, and predicting, that can be distinguished from one another (e.g. Stürmer et al., 2013).

PV can be conceptually construed as a knowledge-based process (e.g. Stürmer et al., 2013) that, depending on the focus of the analysis, requires the use of appropriate theoretical knowledge. In order to be able to professionally recognize the use of instructional-supportive strategies, analysers must fall back on theoretical knowledge about instructional support. They need this knowledge in order to first identify effective learning situations, and then, interpret them in correspondence with the three subprocesses (Stürmer et al., 2013) mentioned above. Thus, analysers can: 1. Describe in a theory-based manner, how the use of instructional supportive strategies took place, 2. explain to what extent they perceive the teacher's use of the strategy as appropriate, and 3. make predictions about which effect these applied strategies could have on pupils' learning. Evidence suggests that the PV of instructional support (PVIS) in primary science lessons that is focused on here is a special type of subject-specific awareness, which – along with knowledge about instructional support – must also rely on specific knowledge about the subject area as well (Steffensky, Gold, Holodynski, & Möller, 2015; Sunder et al., accepted).

Instructional support will be defined in this article in accordance with the concept of scaffolding (Wood, Bruner, & Ross, 1976). Analog to the metaphor of building a scaffold, an experienced teacher supports learners by building up a (learning) framework that enables learners to solve tasks which, without this supporting framework, they would not be able to manage on their own. As soon as the learners are in a position where they are able to work more independently this learning framework can be removed. The assistance of the teacher should then be withdrawn by adaptively being adjusted to the abilities of the learner. This is also referred as fading (van de Pol, Volman, & Beishuizen, 2010).

The use of instructional support strategies should be adapted in such way that the learners are supported as much as necessary, but are nevertheless always challenged cognitively (Reiser, 2004). Drawing on Reiser's (2004) distinction in these two areas, problematizing and structuring, we distinguish actions of instructional support, which have the potential to activate learners cognitively (problematizing) from those that structure the teaching content (structuring) (Meschede, Steffensky, Wolters, & Möller, 2015, s. Table 1).

Research findings point to the relevance of such instructional support strategies (Lipowsky, 2015); this is especially true for individual strategies in primary science education (Hardy et al., 2006; Ewerhardy, Kleickmann, & Möller, 2012).

Table 1. Strategies of instructional support in science classes in primary school (Meschede et al., 2015)

Strategies with the goal of cognitive activation	Strategies with the goal of structuring content
explore pupils' concepts and underlying thought processes	provide clarity of purpose
illustrate limited explanation-power of ideas	ensure the conceptual clarity of teacher and student statements
initiate the development of a new concept	structure discussion by focusing attention
foster reasoning processes of generalization	structure talks through use of summarizing methods
encourage the application of the developed concept	support oral statements with appropriate illustrations
stimulate communication and negotiation of meanings	

CASE STUDIES IN TEACHER EDUCATION – TEXT VS. VIDEO

Generally casework with video harbours a great deal of potential: Videos allow us, for example, to look at certain lessons excerpts repeatedly, to analyse them, and discuss them together (Reusser, 2005), whereby theories can be applied to practical situations in the video sequence selectively. In doing so, the lesson that is shown is depicted quite authentically in its simultaneity and complexity (Koehler, 2002). In addition, the contents of the video are presented audio-visually, which – according to the *dual-processing theory of working memory* (Mayer & Moreno, 1998) – appears to be advantageous for the processing of information that is handled in a parallel manner in the auditory domain of the working memory (e.g. written or spoken texts) and in the visual area of the working memory (e.g. graphics or (moving) images).

The modern medium of video is not the only one that has advantages however. Text-based cases also have media-specific advantages: Due to its static property, a text for example, allows a sequential approach to case study, through which the analyser is able to focus well on relevant aspects, and irrelevant aspects can be simultaneously neglected. Furthermore, text-based cases can be constructed in advance so that insignificant content, which may provide a distraction, is not part of the exercise. This can facilitate a focused analysis.

Several studies have dealt with the promotion of PV by working with case studies. Harrington (1995) could show that pre-service teachers were able to improve their „professional reasoning" (p. 212) by analysing text-based classroom studies within the framework of an intervention. Under professional reasoning Harrington comprehends, among other things, the identifying of relevant classroom features and the making of connections to theory. The fostering of PV by working with video-based cases was also successful in other studies in respect to various points of analysis (e.g. Sherin, 2007; Stürmer et al., 2013) in particular focalized aspects. PVIS in primary science lessons could also be promoted topic-specifically through an intervention in which text and video-based classroom analyses were used. Thus, it appears that it is possible to foster PV through text-based, video-related or text and video-based case studies. This suggests a possible benefit of video for the promotion of professional development of (pre-service) teachers. It remains unclear up to now, however, whether the use of videos is actually needed or whether working solely with traditional case analyses, purely on the basis of written texts, would suffice to promote the professional vision of pre-service teachers. Therefore, in this paper the following question is studied: To what extent can the professional vision of pre-service teachers regarding instructional support strategies in primary science education be promoted through instructional interventions with or without videos?

METHOD

Study Sample

In order to answer the above-mentioned question, three groups were compared with each other: An intervention group in which classroom instruction was analysed on the basis of text cases (IG-T, $n = 31$; age, $M = 23.26$, $SD = 3.19$; 94% female), another intervention group in which instruction was analysed using both text and video-based casework (IG-TV, $n = 28$; age, $M = 23.15$, $SD = 2.55$; 79% female), and a control group without intervention (CG, $n = 35$; age, $M = 22{:}46$, $SD = 2{:}03$; 81% female). The students of all three groups were primary school, pre-service teachers studying the subject “primary science education”. The IGs were students at the University of Münster, while the CG studied at the University of Augsburg.

Intervention Design

The video-based intervention was already tested in Sunder et al. (2015) modelled after the *Lesson Analysis Framework* (Santagata & Guarino, 2011). In the present study, both intervention forms (IG-T and IG-TV) made use of the concept of Sunder et al. (2015). The intervention was designed as follows (see Figure 1): First, the students learnt theoretical foundations of instructional support as well as content and pedagogical content knowledge on the lesson topic, *floating and sinking.* Based on this knowledge, they then analysed the teaching of an outside, experienced teacher in this subject in terms of the appropriate use of instructional support strategies. To this end, they described and explained the use of the strategies in a theory-based manner and, if appropriate, gave alternatives for teacher behaviour, which usually included a prediction of the effect of the teacher’s action on the learning of pupils. Following this phase of external analysis, the students themselves conducted micro-teaching on the topic of *floating and sinking.* In the course of this, the students – in groups of three – taught a double lesson on this subject to a small group of three to four second-graders. This was followed by an analysis of the micro-teaching sequence, which was carried out in a similar procedure as the external analysis.

The interpretation of teaching examples of outside teachers took place in the IG-T based on transcripts that were enriched with contextual information. For the IG-TV, the lessons of the teachers observed were additionally analysed on the basis of videos. All of the students’ own lessons in the IG-T were analysed with the help of notes that the group members took during the micro-teaching sessions and on the basis of the students’ own memories. In the IG-TV, on the other hand, the micro-teaching sessions of the students were filmed. These videos were used along with the notes taken by the group members for the analysis of their own teaching (see Figure 1).

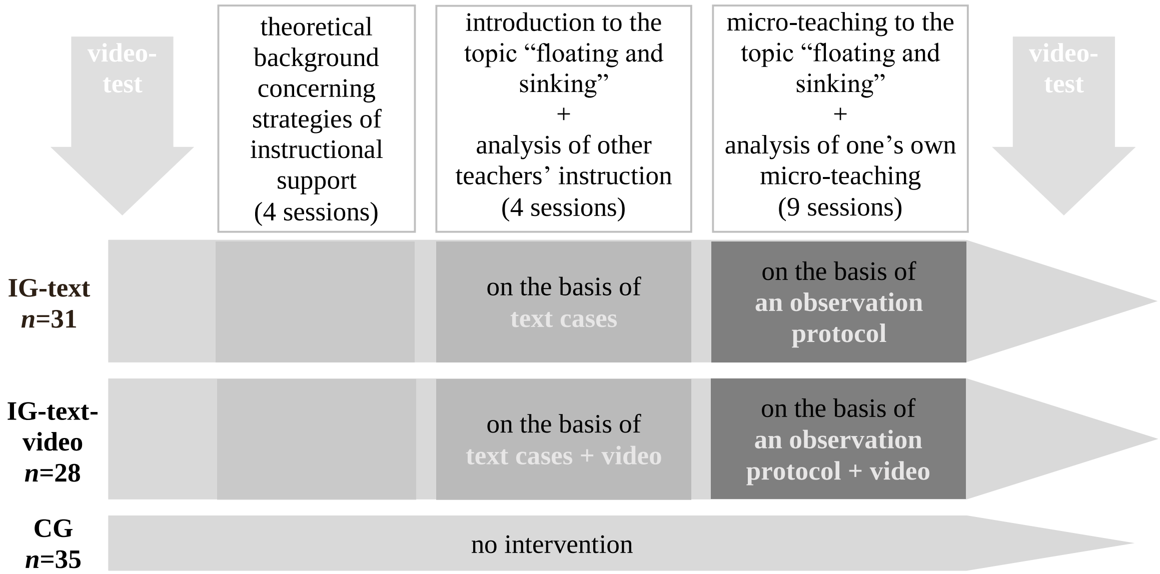

Figure 1. Intervention Design

Instrument

In order to capture PVIS, the students of the three groups completed a standardized video-based test (Meschede et al., 2015). The two IGs completed the test both before and after the interventions, the CG was also tested twice using the same time intervals between tests as the IGs (see Figure 1). This video-based test included six video clips about the topics, *floating and sinking* (three clips) and *evaporation and condensation* (three clips). After the students have viewed the scenes once, they assess statements for each clip on a four-point rating scale. These individual evaluations will be compared with a master rating (for information on how the rating was created, see Meschede et al., 2015); by complete agreement 2 points, with a match in tendency 1 point, and for opposing assessments 0 points will be awarded. In total, the PVIS will be detected with 68 items; the scale *Professional Vision of Instructional Support for the Topic Floating and Sinking (PVIS_F&S)* consists of 26 items, the scale *Professional Vision of Instructional Support for the Topic Evaporation and Condensation (PVIS_E&C)* includes 42 items (see Table 2). The reliabilities of both scales are good to very good.

Table 2. Scales measured by the video test, example items (Wolters, 2014), number of items within scales, reliabilities of scales

Scales	Example item	Rating scale	Item number	α[c]
PVIS_F&S[a]	In this scene, pupils examine the presumption that the material determines whether an object floats or sinks.	*1 = I agree* - *4 = I disagree*	26	pre[d]: .862 post[d]: .881
PVIS_E&C[b]	Pupils are given enough opportunities to apply the experiment's results by themselves.	*1 = I agree* - *4 = I disagree*	42	pre[d]: .93 post[d]: .935

[a] *Professional Vision of Instructional Support for the Topic Floating and Sinking*, rating scale based on Meschede et al. (2015); [b] *Professional Vision of Instructional Support for the Topic Evaporation and Condensation*, rating scale based on Meschede et al. (2015); [d] reliability, Cronbach's alpha; [d] this scale was raised before and after the seminar.

In order to answer the question, techniques of covariate analysis were used. To compare the increase in PVIS between groups, a one-way ANCOVA was calculated for each topic with the dependent variables (DV) *PVIS_F&S* and *PVIS_E&C* for the second sample point and the group variable (IG-T, IG-TV, CG) as the between-subject factor. The values for PVIS for the first sample point were taken into consideration as covariates. The constructivist and transmissive beliefs of the pre-service teachers in regards to teaching and learning were drawn upon as control variables, since the literature shows that professional vision correlates with beliefs regarding teaching and learning (e.g. Cho & Huang, 2014).

For the purpose of comparing the groups, repeated contrasts were subsequently calculated. By doing so the change in PVIS in the individual topics was compared between the CG and the IG-T and, in addition, between the IG-T and the IG-TV.

RESULTS

The variance analysis tests showed, that the three groups in *PVIS_F&S* differed significantly from one another, with a medium effect size in learning gains, $F(2, 88) = 3.204$, $p = .045$, $\eta_p^2 = .068$. The subsequent analysis of repeated contrasts that was used showed that the IG-TV in the instructed topic of *floating and sinking* in comparison to IG-T significantly improved PVIS with a medium effect size, $d = 0.58$, $p = .03$, whereas in this regard there was no difference between IG-T and CG, $d = 0.01$, $p = .942$. In the topic that was not instructed in the interventions, *evaporation and condensation*, the three groups did not differ in regard to their PVIS-changes, $F(2, 88) = .806$, $p = .45$, $\eta_p^2 = .018$ (see Figure 2 for illustration of results).

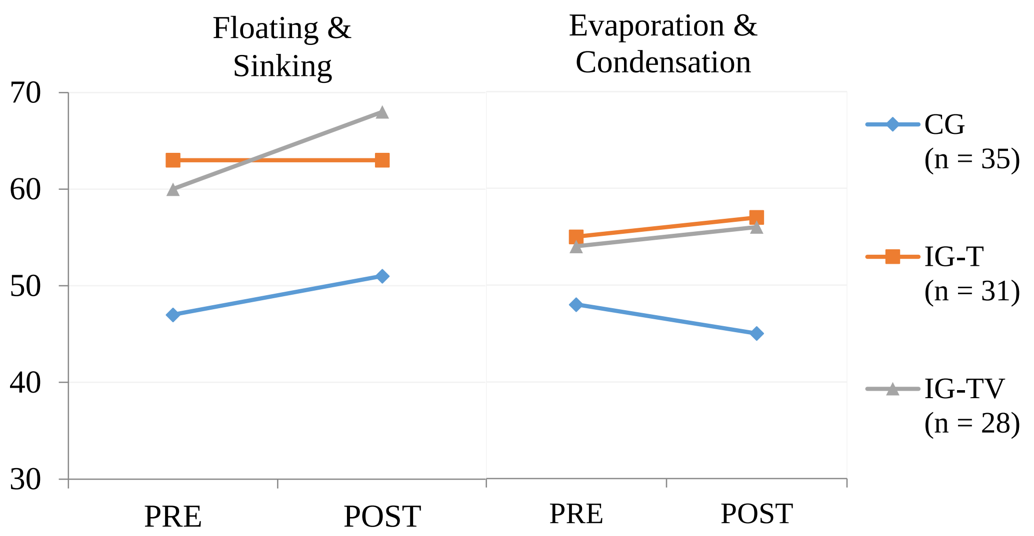

Figure 2. Means of pre- and post-tests of the scales *Professional Vision of Instructional Support for the Topic Floating and Sinking* and *Professional Vision of Instructional Support for the Topic Evaporation and Condensation*, divided by group (CG = control group; IG-T = intervention group, text; IG-TV = intervention group, text and video).

DISCUSSION AND CONCLUSIONS

The results of the study suggest that the additional use of video appears to facilitate topic-specific fostering of PVIS, since the IG-TV was able to improve PVIS as compared with the IG-T in the subject covered, *floating and sinking.* It is possible that the work with text and video-based cases was successfully combined so that students were able to profit from both mediums. The fact that the IG-T compared to the CG could not improve its PVIS, suggests however that analysis of text cases alone is probably insufficient for improving PVIS. On possible explanation for this result is, for example, that the text cases used could not illustrate lessons in their complexity, so that students could adequately train the application of theoretical knowledge in the situation. Videos on the other hand allow a fairly authentic picture of complex teaching events (Koehler, 2002), which was potentially conducive to enhancing the PVIS. Moreover, these results go hand in hand with assumptions of the *dual-processing theory of working memory* (Mayer & Moreno, 1998), which theorizes that videos appear to be advantageous for the processing of visual and auditory information presented.

That the PVIS could be promoted exclusively for specific topics, lets assume that, for analysis of instructional support in the classroom, specific knowledge of the topic of instruction is required. In the interventions, the pre-service teachers had various learning opportunities in which they could acquire knowledge about *floating and sinking* and could train the application of that knowledge. At this point, however, it can only be assumed that they could improve their topic-specific knowledge. To prove this assumption, appropriate tests should be used for capturing (pedagogical) content knowledge in future studies.

In view of (future) teacher training education, these results lead us to conclude that, PV can be fostered early on as an important component of teaching expertise (e.g. Sherin 2007), whereby its promotion with a focus on instructional support was only successful in the instructed topic. Perhaps therefore, it appears necessary to train students' PV not only by way of example on one single topic. Since it will hardly be possible in the context of university education to establish such training programmes in every topic of each subject, it may be worthwhile to train students in a way that enables them to acquire the necessary knowledge for self-sufficiently acquiring PV in various topics and subjects. There is a need for further research in this area in order to test whether it is, for example, sufficient for students to acquire appropriate professional and pedagogical content-knowledge on a topic, if they have already been trained in analytical methods and the application of knowledge has been illustrated on an exemplary topic. It could possibly be necessary for students to not only acquire knowledge, but also to actually practice applying it in classroom cases. In addition, the results of Hellermann and colleagues (2015) allow us to assume that it may be crucial for the students – as in the intervention presented here – to implement such instruction themselves. It is possible that students only first begin to delve intensively into the use of instructional support through their own teaching in a specific topic.

NOTES

1. This book chapter corresponds to the German articles: Sunder, C., Todorova, M., & Möller, K. (under review). Verbessert der Einsatz von Videos in Bachelor-Lehrveranstaltungen das professionelle Wahrnehmen von Szenen aus dem naturwissenschaftlichen Sachunterricht? [Does the use of video in courses at the Bachelor level improve professional vision concerning scenes taken from primary science instruction?] and Sunder, C., Todorova, M., & Möller, K. (accepted). Lohnt sich der Einsatz von Videos, um die professionelle Wahrnehmung von Sachunterrichtsstudierenden zu fördern? Ein Vergleich der Arbeit mit textbasierten und text- und videobasierten Fallanalysen [Is it worthwhile to use videos in order to foster elementary science pre-service teachers' professional vision? Comparing text-based with text and video-based case analyses].

REFERENCES

Blomberg, G., Renkl, A., Sherin, M.G., Borko, H. & Seidel, T. (2013). Five research-based heuristics for using video in pre-service teacher education. *Journal for Educational Research Online*, 5 (1), 90-114.

Cho, Y. & Huang, Y. (2014). Exploring the links between pre-service teachers' beliefs and video-based reflection in wikis. *Computers in Human Behavior, 35*, 39-53.

Clark, R. (1994). Media will never influence learning. *Educational Technology Research and Development, 42* (2), 1042-1629.

Ewerhardy, A., Kleickmann, T. & Möller, K. (2012). Fördert ein konstruktivistisch orientierter naturwissenschaftlicher Sachunterricht mit strukturierenden Anteilen

das konzeptuelle Verständnis bei den Lernenden? [Does Constructivist-Oriententeed Science Instruction with Structuring Elements Foster the Conceptual Understanding of Learners?] *Zeitschrift für Grundschulforschung, 5* (1), 76-88.
Hardy, I., Jonen, A., Möller, K. & Stern, E. (2006). Effects of instructional support within constructivist learning environments for elementary schools students' understanding of "floating and sinking". *Journal of Educational Psychology, 98* (2), 307-326.
Harrington, H. (1995). Fostering reasoned decisions: Case-based pedagogy and the professional develpment of teachers. *Teaching & Teacher Education, 11* (3), 203-214.
Hellermann, C., Gold, B. & Holodynski, M. (2015). Förderung von Klassenführungsfähigkeiten im Lehramtsstudium: Die Wirkung der Analyse eigener und fremder Unterrichtsvideos auf das strategische Wissen und die professionelle Wahrnehmung [Fostering of classroom management skills in teacher training programmes: The effect of analysing videos of one's own and others' teaching on strategic knowledge and professional vision]. *Zeitschrift für Pädagogische Psychologie, 47* (2), 97-109.
Koehler, M. (2002). Designing case-based hypermedia for developing understanding of children's mathematical reasoning. *Cognition and Instruction, 20* (2), 151-195.
Koehler, M., Yadav, A., Phillips, M. & Cavazos-Kottke, S. (2005). What is video good for? Examining how media and story genre interact. *Journal of Educational Multimedia and Hypermedia, 14* (3), 249-272.
Kozma, R. (1994). Will media influence learning? Reframing the debate. *Educational Technology Research and Development, 42* (2), 7-19.
Lipowsky, F. (2015). Unterricht [Classroom teaching]. In E. Wild & J. Möller (Eds.), *Pädagogische Psychologie* (p. 69-105). Heidelberg: Springer.
Mayer, R. & Moreno, R. (1998). A split-attention effect in multimedia learning: Evidence for dual processing systems in working memory. *Journal of Educational Psychology, 90* (2), 312-320.
Meschede, N., Steffensky, M., Wolters, M. & Möller, K. (2015). Professionelle Wahrnehmung der Lernunterstützung im naturwissenschaftlichen Grundschulunterricht - Theoretische Beschreibung und empirische Erfassung [Professional vision on science lessons in primary school – Conceptualization and measurement]. *Unterrichtswissenschaft, 43* (4), 317-335.
Moreno, R. & Valdez, A. (2007). Immediate and delayed effects of using a classroom case exemplar in teacher education: The role of presentation format. *Journal of Educational Psychology, 99* (1), 194-206.
Pauli, C., Reusser, K., Brühwiler, C., Heitzmann, A., Niggli, A., Tettenborn, A. et al. (2014). Videobasierte Fallarbeit/Kasuistik in der Lehrerinnen- und Lehrerbildung [Video-based case study/casuistry in teacher training]. *Beiträge zur Lehrerinnen- und Lehrerbildung, 32* (2).
Reiser, B.J. (2004). Scaffolding complex learning: The mechanisms of structuring and problematizing student work. *Journal of the Learning Sciences, 13* (3), 273-304.
Reusser, K. (2005). Situiertes Lernen mit Unterrichtsvideos [Situated learning with classroom videos]. *Journal für LehrerInnenbildung, 5* (2), 8-18.
Rosaen, C.L., Lundeberg, M., Cooper, M., Fritzen, A. & Terpstra, M. (2008). Noticing noticing: How does investigation of video records change how teachers reflect on their experiences? *Journal of Teacher Education, 59* (4), 347-360.
Santagata, R. & Guarino, J. (2011). Using video to teach future teachers to learn from teaching. *Mathematics Education, 43*, 133-145.

Sherin, M.G. (2007). The development of teachers´ professional vision in video clubs. In R. Goldman, R. Pea, B. Barron & S. Derry (Eds.), *Video research in the learning sciences* (p. 383-395). Hillsdale, NJ: Erlbaum.

Shulman, L. (1992). Toward a pedagogy of cases. In J. Shulman (Eds.), *Case methods in teacher education* (p. 1-30). New York: Teachers College Press.

Steffensky, M., Gold, B., Holodynski, M. & Möller, K. (2015). Professional vision of classroom management and learning support in science classrooms - Does professional vision differ across general and content-specific classroom interactions? *International Journal of Science and Mathematics Education, 13*, 351-368.

Stürmer, K., Könings, K.D. & Seidel, T. (2013). Declarative knowledge and professional vision in teacher education: Effect of courses in teaching and learning. *British Journal of Educational Psychology, 83*, 467-483.

Sunder, C., Todorova, M. & Möller, K. (2015). Kann die professionelle Unterrichtswahrnehmung von Sachunterrichtsstudierenden trainiert werden? – Konzeption und Erprobung einer Intervention mit Videos aus dem naturwissenschaftlichen Grundschulunterricht [To what extent can elementary science pre-service teachers' professional vision be fostered? Designing and testing an intervention with videos on elementary science instruction]. *Zeitschrift für Didaktik der Naturwissenschaften.* doi: 10.1007/s40573-015-0037-5

Sunder, C., Todorova, M. & Möller, K. (accepted). Lohnt sich der Einsatz von Videos, um die professionelle Wahrnehmung von Sachunterrichtsstudierenden zu fördern? Ein Vergleich der Arbeit mit textbasierten und text- und videobasierten Fallanalysen [Is it worthwhile to use videos in order to foster elementary science pre-service teachers' professional vision? Comparing text-based with text and video-based case analyses]. *Unterrichtswissenschaft.*

Sunder, C., Todorova, M., & Möller, K. (under review). Verbessert der Einsatz von Videos in Bachelor-Lehrveranstaltungen das professionelle Wahrnehmen von Szenen aus dem naturwissenschaftlichen Sachunterricht? [Does the use of video in courses at the Bachelor level improve professional vision concerning scenes taken from primary science instruction?]

van de Pol, J., Volman, M. & Beishuizen, J. (2012). Promoting teacher scaffolding in small-group work: A contingency perspective. *Teaching and Teacher Education, 28,* 193-205.

Wolters, M. (2014). *Wie kompetent sind (angehende) Lehrkräfte in der professionellen Wahrnehmung kognitiv anregender Situationen im naturwissenschaftlichen Grundschulunterricht?* [How competent are (future) teachers in professional awareness of cognitive activation in primary science education?] Westfälische Wilhelms-Universität Münster.

Wood, D., Bruner, J.S. & Ross, G. (1976). The role of tutoring in problem solving. *Journal of Child Psychology and Psychiatry, 17,* 89-100.

Yadav, A., Phillis, M., Lundeberg, M., Koehler, M., Clouse, K. & Dirkin, K. (2011). If a picture is worth a thousand words is video worth a million? Differences in affective and cognitive processing of video and text cases. *Journal of Computing in Higher Education, 23* (1), 15-37.